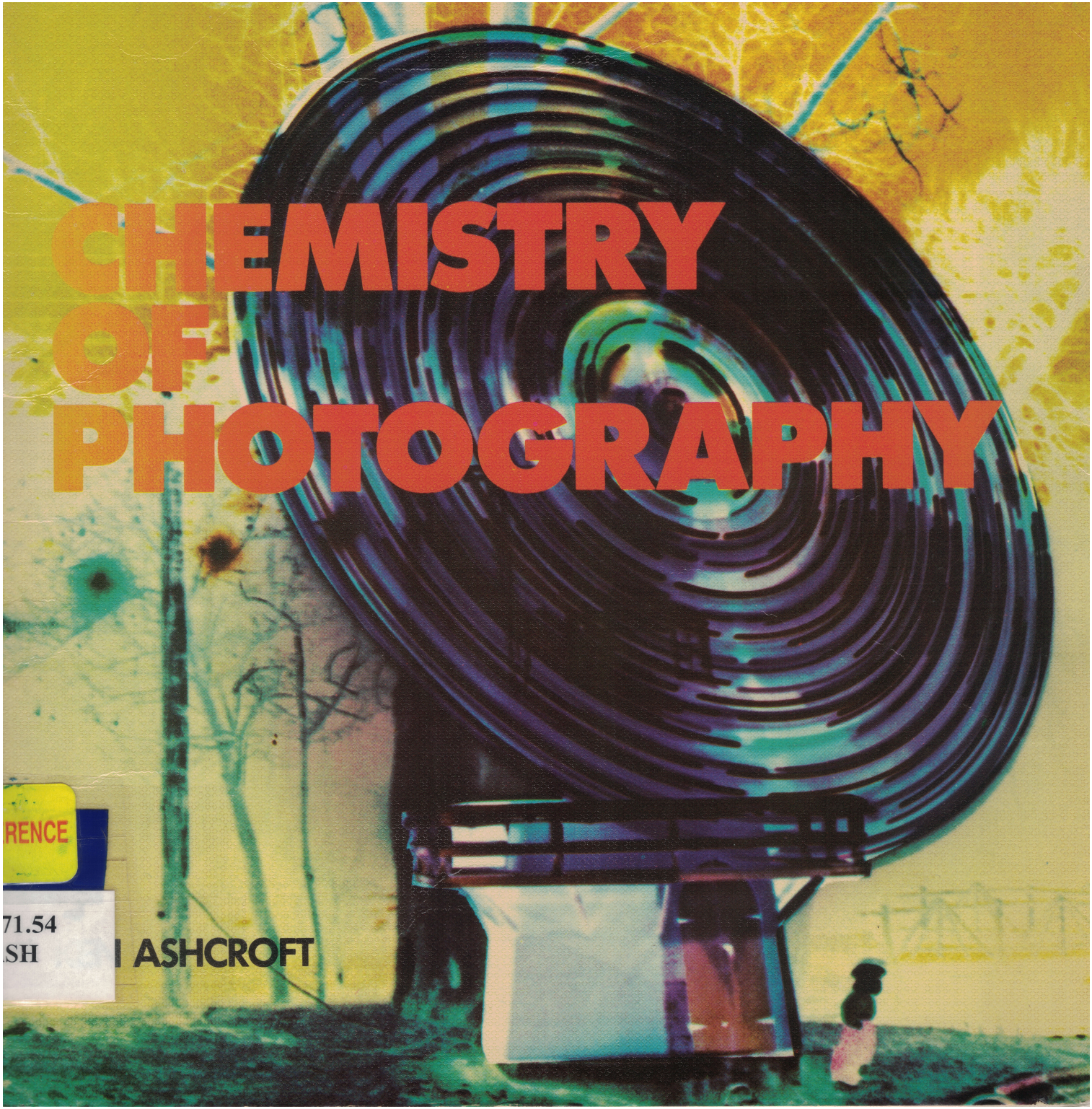
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SI Edition

CHEMISTRY OF PHOTOGRAPHY

KEN ASHCROFT A.R.P.S.

The Book Society of Canada Limited, Agincourt, Canada
John Murray, London

The photograph on the cover – of Christmas illuminations at Simcoe, Ontario – was taken as a colour transparency. The slide was placed in the enlarger so that the print appeared as a negative both in tone value and in colour. (The original is reproduced in the colour section of this book.) Technical details: 10 second exposure at f4 using Fujichrome film. The camera was held against a tree to ensure that it did not move. Remember to take your tripod when you might be making long exposures!

The illustration on the title page is an example of the use of filters in photography. Without a yellow or orange filter over the camera lens, the white clouds would not have been well defined against the bright blue sky when using monochrome film. Technical details: Kodak Panatomic-X film, exposed at 1/1000 second at f4 from a moving passenger train, using a 2X yellow filter; developed in Rodinal, 1:100 dilution for 12 minutes at 20°C.

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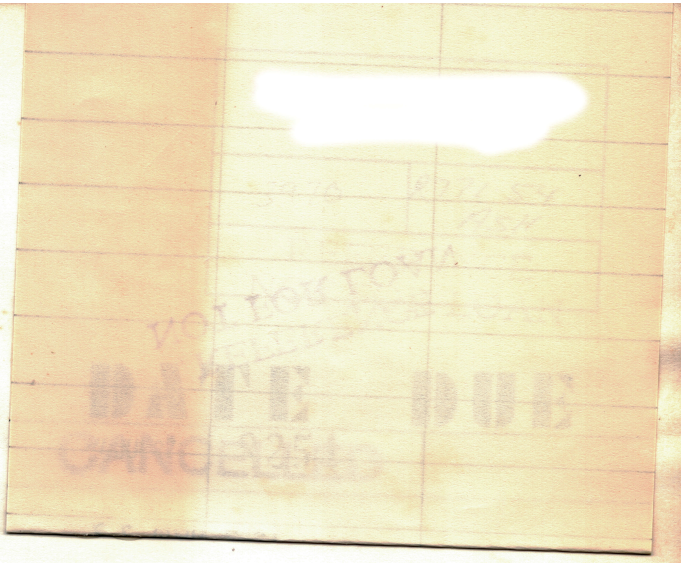

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To the teacher

The introduction to photography in this book is unconventional in that students use simple apparatus and their knowledge of basic chemistry to create pictures. Perhaps this will help dispel the widely-held (and heavily-advertised) notion that success in photography requires expensive equipment.

In this series, as revised, only SI units and those derived from or compatible with SI have been used. Also, every effort within reason has been made to conform to the IUPAC system of nomenclature and spelling. It should be pointed out to students that IUPAC names are unfamiliar to chemical supply companies and almost unheard of in camera shops. A request for potassium hexacyanoferrate(III) would prove fruitless, though a bottle labelled 'potassium ferricyanide' were in plain view on a shelf.

While the point (.) has been used as the decimal marker, it should be made clear that the comma (,) is used for this purpose extensively throughout the world – and more immediately in French-language texts in Canada.

Author's acknowledgments

The author would like to thank the people who assisted in preparing this book. These include Ms. Susan Judge and Mrs. Catherine Attridge, who prepared the typescript. Graham Worthington, who checked the proofs, and Peter Foulds, Bruno Gos, John May, Ralph Winterle and Stan Whipp who gave advice, helped with producing photographs, and tested experiments. The project would never have materialized without inspiration from Ted Williams, Karl Hughes, A.R.P.S., and from Rudi Krauth of the Leica School in Wetzlar, West Germany.

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Popular Photography 4-2 (adaptation)

1 What is photography?

Photography is a method of recording an image on a sensitive surface. The recording device used in a camera.

The user of the camera *selects* the boundaries, or frame, of the image recorded. Therefore photography differs from the use of a simple copying device because the person using the camera always makes some artistic choice. This is part of the fascination that makes photography the world's most popular hobby.

Through owning a camera and buying gadgets to fit onto it, photographers can satisfy the urge to collect which many people have. Some photographers make money from their hobby by finding markets for the images they create.

Chemistry of Photography is intended for those who have a basic knowledge of chemistry and would like to find out how chemistry and physics are involved in the basic steps of picture-making. In this book you will find brief references to the history of photography, hints on buying a first camera and ideas for picture-taking. A list of books is given on page 45 so that you can read more about these aspects of photography and others.

Whatever you goals are in learning about photography, you will not make real progress until you start doing things for yourself. (This will also save you money as you go.) Formulas are given in Chapter 4 for making photographic solutions. You will be a better photographer for understanding what happens in your camera and to your film when it is processed, even if you do not continue to process your own materials.

The word 'photography' comes from two Greek words meaning 'light-drawing'. To understand what the term 'photography' signifies, you must first think about light itself.

The nature of light

You may know from your previous studies that light is one kind of electromagnetic wave. It therefore possesses energy and travels with the same velocity as other electromagnetic waves. Light waves have different wavelength and frequency from other electromagnetic waves. Of all these, only light waves can be registered by the human eye.

When your eye registers light waves of longer wavelength (lower frequency) you see a red colour. Light of shorter wavelength (higher frequency) registers as blue. Remember these facts when you investigate colour photography in Chapter 6.

How is an image recorded?

The colour or colour intensity of many materials changes when exposed to light of a certain wavelength. These materials include:

(a) your skin;
(b) photocopying materials;
(c) blueprinting solution used in a drafting office;
(d) 'photo-grey' spectacle lenses;
(e) photographic film.

Of all these materials, film is the most sensitive to light. Today, all film in general use is coated with compounds of the element *silver*. Note: if you spill silver nitrate solution on your hands, dark stains will form when they are exposed to light. Spills should be rinsed first with sodium thiosulphate solution, then with water (see page 6).

● *Experiment 1.1*
How do silver compounds react to light?
(One period)

Saturate four pieces of filter paper in 0.1 per cent silver nitrate solution. Set one piece aside. Immerse the other three in the following solutions:

(a) one in 1 per cent sodium or potassium chloride solution;
(b) one in 1 per cent sodium or potassium bromide solution;
(c) one in 1 per cent sodium or potassium iodide solution.

Record the appearance of each filter paper. Take four pennies and use them to cast a shadow from a very bright light source. You can do this easily in one of two ways.

(1) Place the filter papers on a dark card, put a coin in the centre of each, and expose the papers to the direct rays of the sun.
(2) Place the pennies on a sheet of glass, put a filter paper on each, and place the sheet of glass on an overhead projector. Switch on.

Observe each filter paper in turn for 2 minutes over a period of 20 minutes. Record your observations. Dry the papers and keep them in your notebook. Look in a reference book to find the solubilities of the silver halides. Why is silver fluoride not used in photography?

The first photographs were made using materials such as those listed above. However, further experiments showed that when the silver compounds were mixed with gelatin, the resulting 'emulsion' had much better photographic properties.

What is gelatin? How is it used in the household? How is gelatin obtained?

The worlds largest camera required a team of 15 operators. It is shown in *The Guinness Book of World Records*.

All nineteenth century cameras used an emulsion which was poured onto thin glass plates before it cooled. It thus formed a thin *film*. Preparing and transporting these plate films made photography far more tedious than it is today. (Certain types of specialized cameras still use glass plates.)

Most photographers now use *roll-film* cameras. In these, the emulsion used is coated onto a strip of plastic, and so a number of pictures can be taken without the need to reload the camera. The strip of plastic is usually cellulose acetate, although plastics such as mylar or estar are used when it is important that the film should not stretch.

For you to consider

(a) Write equations for the changes which took place in Experiment 1.1.
(b) Why are silver compounds always stored in brown bottles?
(c) What can you find out about the Calotype process and the Daguerrotype process?
(d) What is shown on the earliest known photograph? For how long was the film exposed?
(e) If photographic images are made of silver, why are they black and not shiny?

Figure 1-1. This photograph, taken in the 1860s, is of William Notman, a Scot who emigrated to Canada in 1856. He became a famous photographer through his entries at international exhibitions, and was appointed photographer to the Queen. Five hundred thousand photographs taken all over Canada by Notman and his staff provide an invaluable historical record. The collection is in the Notman Photographic Archives in McGill University's McCord Museum, Montreal.

There are three basic steps in producing monochrome (black and white) prints:

(a) exposing the film;
(b) developing the negatives;
(c) making the prints.

In this book, these steps are not treated in that order. They are found (a) on page 14, (b) in Experiment 4.1 and (c) in Experiment 2.5 respectively.

Explanations for technical terms used in this book are given on pages 46 and 47.

The basic equipment for a darkroom can be assembled even in a closet. All you need are:

(a) a small area from which all light can be excluded;
(b) a rigid work surface about 3 × 1 metres;
(c) a daylight developing tank, preferably of stainless steel;
(d) a darkroom safelight;
(e) some plastic basins, 30 × 30 × 10 cm;
(f) a running water supply, or two 20-litre plastic pails. The pails are used where rinsing must be carried out in the dark and no running water supply is available. Most steps involving washing do not need to be done in the dark, so that prints or films can be carried to a sink outside the darkroom;
(g) an enlarger: The Zenit Autofocus is of excellent quality, is inexpensive and is easily stored in its own carrying case;
(h) a timing device that can be easily read in a safelight.

Other equipment, such as flasks, beakers and thermometers, can be borrowed from the chemistry laboratory.

2

Making images by development

- *Experiment 2.1 Reducing properties of pyrogallol (Half period)*

If silver bromide is changed to silver metal, then the following reaction must take place.

$$\text{Silver ion} + \text{electron} \longrightarrow \text{silver atom}$$
$$Ag^+ + e^- \longrightarrow Ag$$

Any substance which provides electrons to another atom or ion can be regarded as a reducing agent. Reducing agents are used as *developing* agents in photography.

Set up the apparatus shown in Figure 2-1. Measure the volume of air contained in the beaker. Tilt the flask so that the solutions mix; then shake it from side to side. When the level of the liquid in the trough does not change any more, measure again the volume of gases the beaker contains. What was the change in volume?

Place a lighted splint in the gas in the flask. What happens? What has happened to the air in the flask?

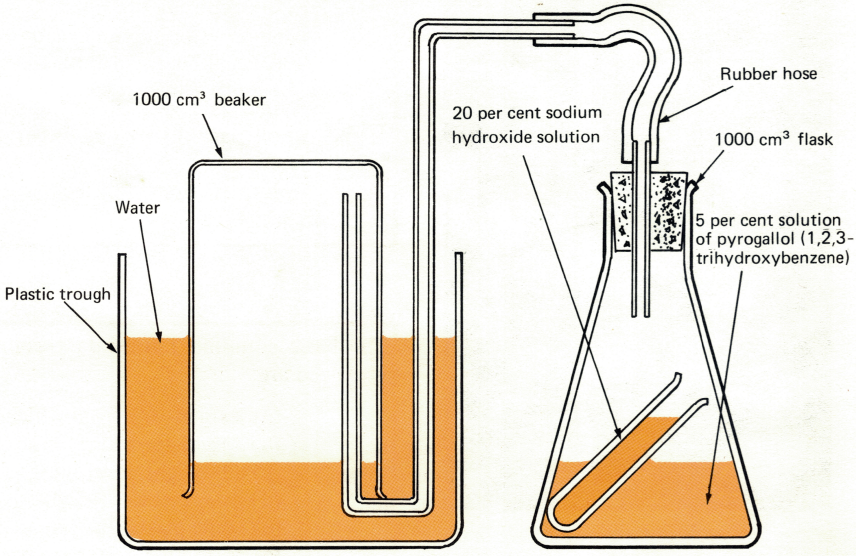


Figure 2-1. Equipment for Experiment 2-1.

Aminoethanoic acid (aminoacetic acid, or glycine) has a simpler formula than any other substance used as a photographic developer. It is

$$NH_2—CH_2—COOH.$$

The molecule forms ions in two ways:

(a) $NH_2—CH_2—COOH \longrightarrow NH_2—CH_2—COO^- + H^+$; and

(b) $H^+ + NH_2—CH_2—COOH \longrightarrow NH_3^+—CH_2—COOH$

The electrons needed to change silver ions to silver atoms can come from the negatively charged particles in the developer. The H^+ ions in (b) are present in the developer solution. This solution must be of the correct concentration as discussed on page 21.

• *Experiment 2.2 Using glycine to develop images (darkroom) (One period)*

Saturate four strips of filter paper as in Experiment 1.1, but this time under darkroom illumination. Place them in a dish on the bench in the darkroom and put a penny on each. Turn on the room lights for 1 minute and then turn them off again.

Make a solution of 30 g of glycine, 150 g of sodium sulfite and 150 g of sodium carbonate in 1 000 cm^3 of water, and pour it into the dish. Watch what happens to the filter papers. In what ways do the papers change in the first 2 minutes? In what ways do they change in the next 8 minutes? After 10 minutes, compare them with those in Experiment 1.1. When the experiment is finished, turn on the room lights and watch what happens to the papers. Why must there be some process following development which will make photographic images permanent?

The results of Experiment 2.1 and 2.2 should make it plain what a photographic developer is. There are many factors to consider before a manufacturer can place a new developer on the market. One of these is the sensitivity of some people's skin to reducing agents. Certain reagents give them a rash.

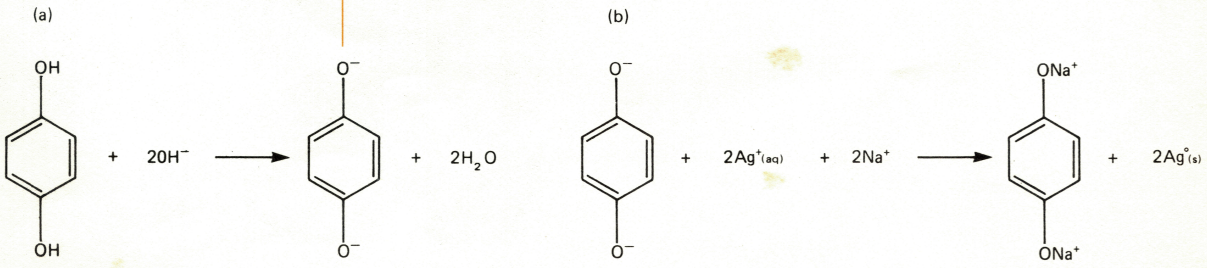
The main chemical factor to consider is the ease with which the developing agent releases electrons. If it releases electrons to the silver too slowly, developing a film will be a lengthy process. A very vigorous developing agent might provide electrons to *all* the silver ions, not just those which have been exposed, and the film would turn completely black.

A developing agent such as pyrogallol (1,2,3-trihydroxybenzene) will give up electrons to atoms of oxygen in the air. If such an agent is left exposed to the air, in a dish, its working life will be very short.

A list of some chemicals that are cheap, non-toxic and that have just the right reducing properties is included on page 21.

How do these chemicals work? Consider the chemical that is part of almost every developer on the market today, hydroquinone (1,4-dihydroxybenzene). Its structure and formula are shown in Figure 2-2(a) along with its reaction with an alkali. You should note that the hydroquinone species in alkaline solution has two negative charges. These can be donated to silver ions. This transfer of electrons turns the ions into silver atoms, as shown in Figure 2-2(b).

Figure 2-2. Reactions of hydroquinone (1,4-dihydroxybenzene) as a developing agent.



• *Experiment 2.3 Using sodium thiosulfate (Half period)*

Make a suspension of silver bromide by mixing 10 cm^3 of 0.1 per cent silver nitrate solution with 10 cm^3 of 1 per cent sodium bromide solution. Divide the suspension into two equal parts by pouring each part into a small flask. To one flask, add an equal volume of 25 per cent sodium thiosulfate solution. Observe any changes that occur.

To the other flask, add an equal volume of glycine solution. Expose the flask to intense light and then add 10 cm^3 of 25 per cent sodium thiosulfate solution. Again, observe any changes that take place.

How is the action of thiosulfate on silver bromide different from its action on silver metal? Try to explain why sodium and ammonium thiosulfate are called 'fixers' by photographers. A useful preparation for a photographic fixer is: sodium thiosulfate 250 g, sodium disulfate(IV) (sodium metabisulfite) 25 g and water 1 000 cm^3. This solution may be stored indefinitely and reused several times.

Making photograms

Printing paper used by photographers is made by coating stiff white paper with an emulsion of gelatin and silver bromide. The emulsion may be given one of several kinds of surface, such as matte, lustre, stipple or silk. For your first work, use the surface called 'glossy'. If you wish, you may use an enlarger in Experiment 2.4 as your light source so that you may become familiar with its function before you do Experiment 2.5. The glycine solution you have used before is not the best for developing paper. Use a solution of a developer such as Bromophen or Dektol, made up according to the manufacturer's instructions. You will also need some fixer solution prepared according to the directions in the previous paragraph.

Figure 2-3. 'Glasses'. This picture was produced without any optical apparatus, by using only a light source, a few common objects, photographic paper, and processing chemicals.

• *Experiment 2.4*
Creating pictures without a negative (darkroom) (One period)

Look in a book on UFO's for evidence of 'trick photography'. Could you use simple darkroom techniques to put a 'UFO' in the sky of one of your photographs?

• *Experiment 2.5*
Making enlargements from negatives (darkroom) One period)

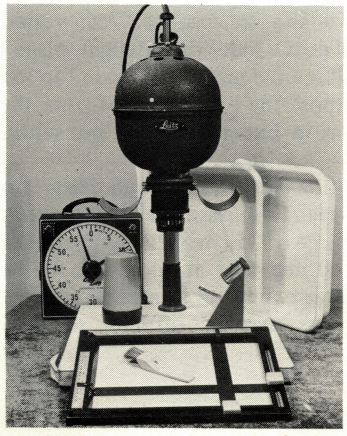


Figure 2-4. Equipment used to make prints from negatives. The easel (at the front), the dishes, the enlarger, and the safelight are essential. The timer, brush and focusing aid are optional.

Cut a piece of photographic paper about 12 cm by 9 cm and place it on an easel. Arrange a few opaque objects in a pattern on the paper. Expose the paper for 10 seconds to light from the enlarger or from a 25-watt bulb at a distance of 30 cm.

Now place the paper in a dish containing enough developer solution to cover the paper. Agitate for 3 minutes or until the dark parts of the paper show no further change. Rinse the paper for 20 seconds in 2 per cent ethanoic (acetic) acid solution and then place it in the fixer for 5 minutes before turning on the room lights to examine your 'photogram'. Repeat the procedure using laboratory glassware or semi-transparent objects, such as ballpoint pens, as sources for your image.

You may have to experiment with different exposure times to obtain images of satisfactory density. If your picture is too dark, try 6 seconds. If it is still too dark, try 3 seconds. If your picture is too light, try 20 seconds. If it is still too light, try 40 seconds.

If you wish to keep the photograms, you must wash off all traces of fixer or they will slowly fade. Rinse the paper for 20 minutes in running water before drying.

For this experiment you will need a negative that has already been processed. Perhaps you would like to reprint an old photograph from your family album.

Put the negative in the holder of the enlarger. Turn on the lamp and find how the three controls of the enlarger (height, aperture and focus) affect the image on the easel. Find a suitable portion of your negative and focus it on your easel, using the widest aperture of the lens. Set the easel to accept a piece of paper 10 cm × 12.5 cm. Close the lens aperture to f8 and turn off the lamp. (The meaning of f numbers is explained on page 11.)

Cut a strip of #3 bromide paper 2.5 cm × 12.5 cm and fit it into the easel. Place a piece of card about 15 cm square over your strip of paper. Turn on the lamp and slide back the card to expose a 2.5 cm-long section of your paper for 5 seconds. Slide the card back a little further and expose another 2.5 cm of the paper. Repeat this procedure three times more and then turn off the lamp. You will now have a strip of paper with five different segments. These segments will represent exposure times of 5, 10, 15, 20 and 25 seconds. This strip is called a 'test strip'.

Develop your test strip in a dish of solution made up of 75 per cent water and 25 per cent paper developer such as Dektol or Bromophen. (These will work like your glycine developer from Experiment 2.2, but will give improved quality.)

Agitate the developer dish once each 10 seconds. Allow the paper to soak in the developer *until you can see no further change after waiting 30 seconds*. This process is called 'developing to finality'. It will take about 3 minutes at room temperature. Take the strip out of the developer and place it in a 'stop bath' consisting of a 2 per cent solution of ethanoic (acetic) acid in water. The paper can remain in the stop bath for many hours without undergoing any noticeable change.

Consult *The Complete Art of Printing and Enlarging* (see Reference Materials page 45) for information on the use of different grades of paper.

Examine your test strip to find which of the five segments indicates the most suitable exposure time. What does it mean if your paper has turned completely black? What might cause your paper to remain white? What adjustments would you make to correct either of these results? If you have made an error in exposure, make the adjustments and print another test strip.

Now examine this test strip and choose the appropriate exposure time to make a full 10 cm × 12.5 cm print. (This time may be anywhere between 5 and 25 seconds.) After exposure, develop to finality as before. Remember that prints always look a little darker under the safelight than they do in daylight.

If your full print is not to your satisfaction, do not try to correct it by changing the development time. The only factor you should vary when making prints is the *time of exposure*. When you have made your prints, you must place the paper in a fixing solution before you turn on the lights. If you fail to do this, the underdeveloped silver bromide on the paper will slowly blacken, as it did in Experiment 1.1.

Throw out your developer and wash the dish. Put enough fixer solution in the dish to cover your prints and soak them for 10 minutes, agitating the dish once each minute. You may then turn on the room lights. (By using this two-dish method of printing, you have no fixer on the bench until the end of the experiment and so there is no chance of contaminating the developer.)

Your prints are still saturated with fixer. This must be removed or it will slowly react with the silver of your image and cause it to fade. You should rinse the prints in running water for 30 minutes.

World sources of silver are declining, and prices are rising rapidly. Reclaiming silver in places that use large quantities of film, such as an X-ray department in a large hospital, could save hundreds of dollars per month.

• *Experiment 2.6*
Contact printing (darkroom)
(One period)

This experiment is a variation of Experiment 2.4. By following Experiment 2.6, you can make a print which is the same size as your negative. Clean your negative and a piece of plate glass to remove all dust. Under the safelight, place your negative on a piece of photographic paper. Place the piece of glass on top to hold the materials flat and in contact. Now expose the paper to light from the enlarger. Use the same exposure technique as in Experiment 2.5, but without a negative in the enlarger.

Contact proof printing is a variation of this technique. Place 6 strips of 5-exposure 135-size negatives in a transparent storage file sheet such as the Negafile. Place the transparent sheet on a piece of 25 cm × 20 cm paper under a sheet of glass and contact-print all your 30 negatives at once. This method is most useful for assessing which are the better exposures in a series of portraits for example, when the individual exposures may be difficult to 'read' as negatives.

• *Experiment 2.7*
Testing used fixer
(Half period)

Place some exhausted fixer in three test tubes. Suspend strips of copper, iron and magnesium in the solution. Observe the changes that take place over periods of 2 minutes, 20 minutes and 24 hours. Try to explain what has happened in terms of electron transfer. Could a similar change occur with an electrolytic process? (See *Action Chemistry*, pages 47 and 73.)

3

How the camera makes images

What sort of film is most suitable?

If you wish to make pictures of your own, you will need a camera. You may decide to borrow one at school or at home, or you may decide to buy a camera. If the latter, you should take many factors into account.

If you buy a camera that uses 126 or 110 film, you will have to pay more for packaging of the film into 'instant-food' containers. Of the two other popular film sizes, 120 and 135, the 135 has several advantages. For use in school, this film can be bought in bulk and loaded very cheaply into special containers called 'cassettes'. Using 33-metre rolls and loading cassettes by hand or with a loading device such as the one in Figure 3-1, you can cut your film costs to less than 2 cents per negative. There are many special types of film available in the 135 size that are not obtainable in other sizes. Unless you become a very advanced photographer and publish your pictures, 135 film will satisfy all your needs.

Figure 3-1. This device stores enough film to load more than 15 lengths of 36-exposures each.

What kinds of camera are available?

There are two basic types of 135 camera. In one you use the camera lens to view the picture. This type is known as a 'reflex camera'. The other type is called a 'viewfinder camera' since you cannot see through the lens, and a separate lens and rectangular opening are used to outline the picture. (See Figure 3-2.)

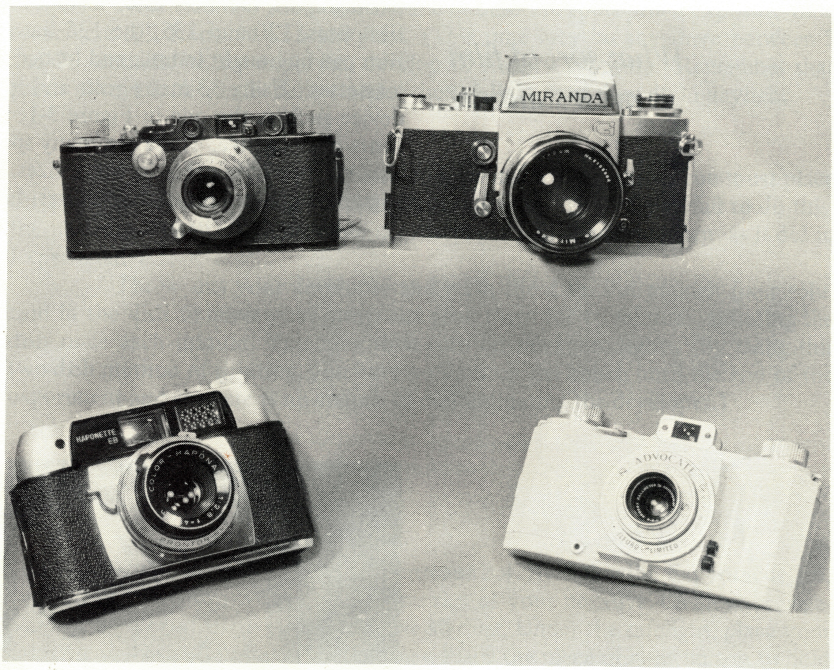


Figure 3-2. One of these cameras has a rangefinder and one is a reflex camera. Can you identify them? Cameras are available to suit everyone's pocket. Used camera prices have remained stable for several years. The cost of the four older models shown, clockwise from the white one, would be about $15, $30, $60, $100.

Features of a 35 mm camera

If you want to take photographs under varying conditions, your camera must have three basic controls: a focusing system, a shutter with variable speed, and an aperture control.

A focusing system for the lens

A focusing system enables you to take photographs of objects at distances closer than 5 metres.

A shutter with variable speed

With a variable-speed shutter, you can take photographs of moving objects. (Remember that the shutter is really an 'opener'.) The shutter has a series of different speeds so that the amount of light it admits can be varied in regular steps. These steps are denoted by numbers that represent fractions of a second. Many modern cameras have the series 1, 2, 4, 8, 15, 30, 125, 250, 500, 1 000. The 250, for example, represents 1/250 of a second. The other numbers represent corresponding fractions of a second.

An aperture control

The aperture control also regulates the amount of light passing through the lens. By using this control, you can adjust for differences in the lighting conditions. It has numbers on it to indicate the relative size of the aperture, or opening. The numbers are obtained as follows. For a lens that focuses distant objects on the film at a distance of 5 cm from its optical centre, we say that the lens has a 5-cm focal length.

The focal lengths of camera lenses are usually expressed in millimetres. For the cameras shown in this chapter, the standard lens has a focal length of 50 mm. If the opening in the lens has a diameter of 25 mm, this aperture is known as f2, since $50/25 = 2$. If the opening is 12.5 mm in diameter, the aperture is denoted f4. A 10 mm opening would be f5.

The lenses on modern cameras have 'click stops' so that the aperture can quickly be adjusted to a set value. The values form part of the series 2, 2.8, 4, 5.6, 8, 11, 16, 22. How much more light passes in a given time through an aperture of f4 than an aperture of f8? Why is there a setting at f5.6?

Can you show mathematically how the series of aperture numbers can be used in conjunction with the shutter speeds? The following combinations of figures should give you a clue:

1/500 s at f2, 1/125 s at f4, 1/30 s at f8.

The most inexpensive way to keep your photographic equipment and negatives clean is to use a rubber ear syringe to create a blast of air that blows away the dust.

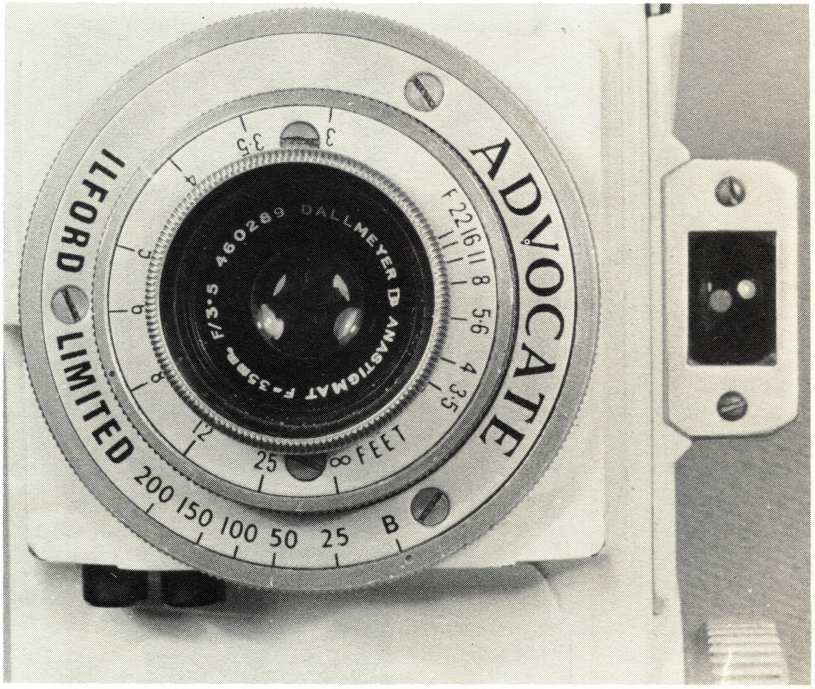


Figure 3-3. All cameras, other than simple 'snapshot' types, have the same three basic controls: f-number, shutter speed, and focusing distance.

Depth of field scale

You must understand one other set of figures before you begin using your camera. The depth of field scale is not a control, but a guide. Think of how the camera forms an image on the film. In Figure 3-5 (a) you can see how the image forms for an object 10 metres away. If the object is 10.5 or 9.5 metres away, the image will be in focus at different distances behind the lens. *Therefore the lens cannot form a clear image of all three objects at the same time.*

Each point of the objects at 10.5 or 9.5 metres will register on the film, not as a point, but as a small circle. This circle is known as the 'circle of confusion'. However, no film can register the difference between a point and a very small circle since there is a limit to the size of the crystals and the thickness of the silver bromide in the emulsion. Therefore, if the circle of confusion in the negative is small enough, it will still register as a point on the print, even after enlargements of ten times or more, and will *appear to be sharply focused*. For each focusing distance, there is a region on either side known as the 'depth of field', in which all objects will register on the film as sharp images.

Depth of field varies with lens opening. At large apertures, the depth of field is small. It increases as the aperture is reduced. Examine a camera and read off the depth of field with the lens set at f5.6 when focused to 10 metres. What is the depth of field when you change the opening to f16?

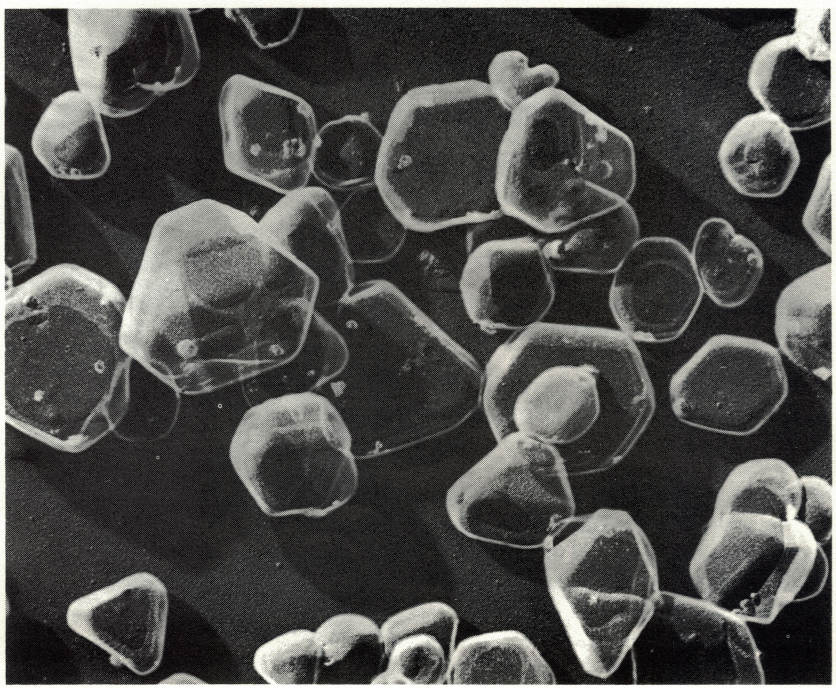


Figure 3-4. Photograph taken with an electron microscope showing unexposed silver bromide crystals.

How is a hologram produced, to give a projected, three-diminsional image?

Find out about Stereo Realist cameras. They are used to make transparencies for use in devices like the Viewmaster. Does your Geography teacher have any books describing some of the many ways in which '3-D' aerial photographs are used commercially? For instance, an expert can estimate the timber value of a forest hundreds of kilometres away without leaving his office desk.

Find out how to use your camera to make stereoscopic photographs by taking two exposures. You move the camera to the right or left so that the distance between the two positions is equal to the distance between your eyes.

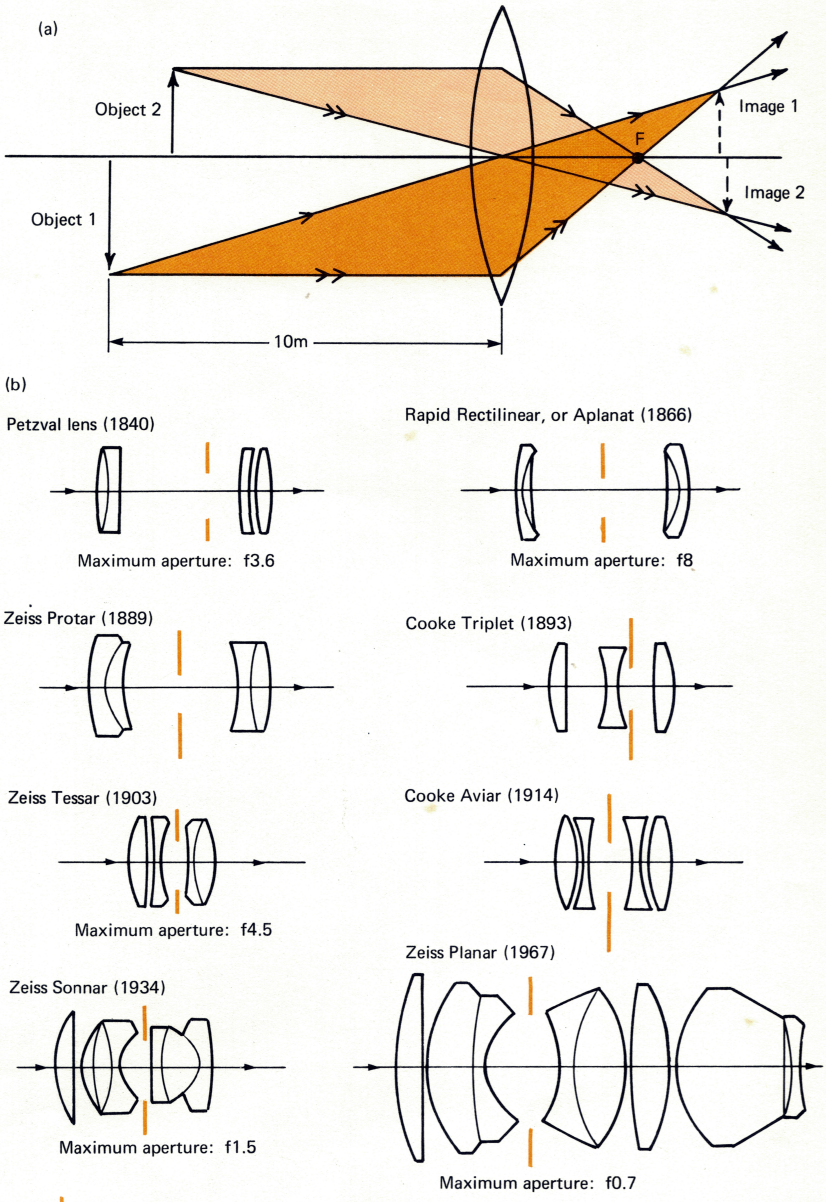


Figure 3-5. (a) Objects at different distances in front of the lens form images at different distances behind it. (b) Stages in the history of lens design.

Setting the controls

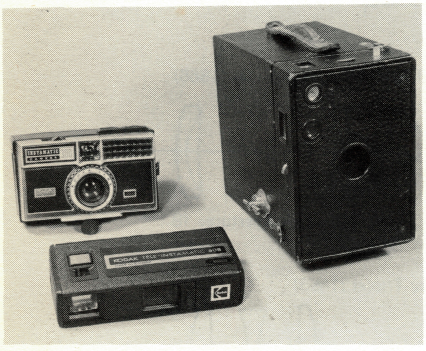


Figure 3-6. These cameras represent seventy years of development of the 'snapshot' type of camera.

Perhaps you can now see why many photographers have difficulty in selecting suitable exposure settings on their camera. There are three variables to consider:

(1) How much light is required to record an image correctly on the film?
(2) Will the shutter speed be adequate to keep the image clearly defined, despite movement of either object or camera?
(3) Will the aperture allow for some error in focusing, or some movement of the subject in the direction of the camera?

When you have considered these three factors, you can set the controls, focus the camera on your chosen subject, then press the shutter release at the best moment.

The simplest cameras for the mass market were originally sold under the slogan, "You press the button and we'll do the rest." There was only one type of film available for these, and the cameras were set to about 1/125 second at f16 and focused to about 4 metres so that on a sunny day the exposure would be adequate. The depth of field would be between 3 metres and infinity. This 'snapshot' type of camera is still available today, although the design has been up-dated. (See Figure 3-6.) Even if you have a more sophisticated camera with adjustable controls, you can still take snapshots, using an ASA 125 film and the settings mentioned above. ASA 125 film can be used in all cameras, but there are many other kinds of film that cannot be used in the snapshot type of camera.

The most important figure associated with any type of film is its speed number. This indicates the sensitivity of the film to light. The system most often used to denote film speed is the ASA system. In using this system, remember that the least sensitive (slowest) films have ASA numbers below 50. Very sensitive fast films have ASA numbers of 400 or more.

Remember this simple rule if you have no other means of working out the exposure:

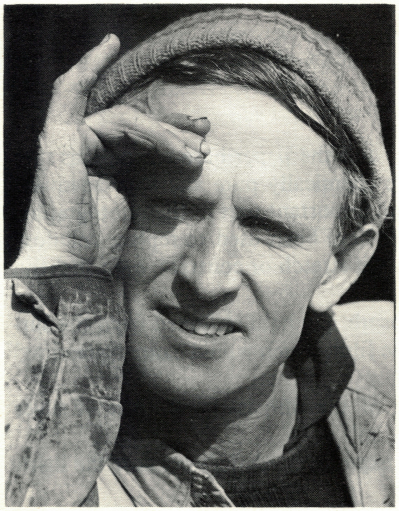
"On a bright sunny day, set the aperture to f16. Use a shutter speed equal to the ASA number."

Thus for a film of ASA 125, your exposure setting would be 1/125 second at f16. What reasons might you have for not using these values, and choosing 1/1 000 second at f8 instead?

For your first roll of film, you should choose an ASA 400. It is easy to choose an exposure for a sunny day. What do you do if the weather is dull? In the film container there will be a slip of paper showing you the outdoor settings for a number of weather conditions. However, the value of an ASA 400 film is that you can use it indoors without a flashbulb. With this film, brightly lit interiors such as a classroom or supermarket, in the absence of sunlight, require an exposure of 1/30 second at f4.

You should obtain a roll of fast film, such as Ilford HP4 or Kodak Tri-X and go round your school taking pictures. You can use your new-found knowledge of photography to make images, perhaps for your yearbook. In the next chapter, you will find out how to turn these images into negatives.

Figure 3-7. Examples of the use of additional lenses. The farmer, and world champion cyclist Graham Webb, were taken with a telephoto lens. A wide-angle lens was used to come within 1 m of the children. The new-born dog-fish was taken at a distance of 25 cm by the method described in Topic 1 (page 36).



4

The latent image

Many people take one aspect of photography for granted. When they have exposed a film, they feel free to have it processed whenever they wish. They may partially use a roll of film in the summer and finish taking the pictures at a Christmas party. Most people never think that anything could happen to the images formed during the summer while the camera lies unused for months.

While the exposure is being made, an image is being recorded on the film. This image cannot be seen until the film is developed. It is called the 'latent' image. At the moment the picture is taken, some change must occur in the silver bromide crystals on the film. What can this change be? How long can the film be stored before the latent image fades? What starts the reaction between the silver bromide and the reducing agent in the developer?

To answer these questions, consider how photographic film or paper is made. Sections of typical film and paper samples are shown in Figure 4-1.

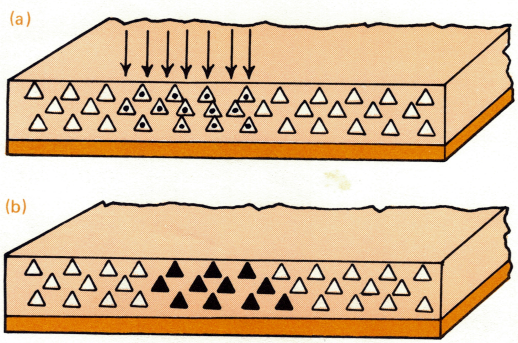


Figure 4-1. Representation of a photographic emulsion (a) as a latent image and (b) after processing. Grains of silver halide suspended in gelatin are shown by the white triangles. The gelatin is coated onto a paper base. Light falling on the emulsion alters some particles in the silver halide. In each exposed grain, the invisible nuclei of a few atoms of free silver – represented by black dots – remain. In (b) grains containing silver nuclei (black triangles) have been completely reduced to silver. These block the light and appear black.

The cellulose acetate (ethanoate) and the paper base act only as supports for the emulsion. As long as they are chemically pure and have adequate tensile strength and flexibility, they play no important part in the photographic process. (Recently other synthetic materials have been used to replace cellulose acetate when it is vital that the film should not stretch or contract, even slightly, on being processed.)

Dyes built into film emulsion absorb any light reflected from the surfaces of the crystals or from the base of the film, which would cause 'spreading' of the image and reduction of its sharpness.

By far the most important part of the film is the mixture of silver bromide and gelatin, often called the 'emulsion'.

You have already performed the experiment that shows how the light-sensitive crystals are produced:

$$AgNO_3 + KBr \longrightarrow KNO_3 + AgBr$$

Would you like to print your photograph on an egg? On page 46 is listed a source of liquid photographic emulsion. Coat this emulsion, in complete darkness, onto the surface of a piece of wood, a cloth, or an egg. After drying, the emulsion can be exposed, developed and fixed in the usual way.

The only difference between the factory method and your laboratory method is that in the factory the crystals of silver bromide are kept in the dark and heated so that they undergo a change called 'ripening'. This change is used to control the size of the crystals, and this in turn determines the grain structure of the film and its sensitivity to light. (Most films of slower ASA rating, which are less sensitive to light, have much smaller crystal size than the faster, more sensitive films.)

The other component of the emulsion – the gelatin – is not subject to chemical control because it is a natural product. However, it is selected, blended and purified very carefully. The only real test to find out whether a gelatin sample is suitable for photography is to make an emulsion and try to produce images with it.

The gelatin has two functions:

(1) It supports the silver bromide crystals in a medium which is flexible and permeable to developing agents.

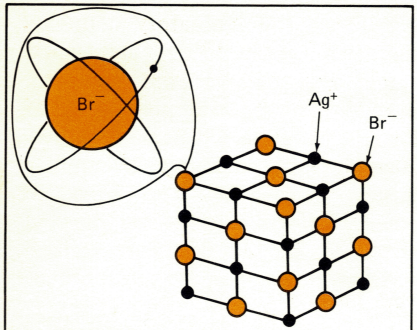
(2) It helps to form the latent image, both by making the crystals more sensitive to light and by accepting electrons and bromide ions from the exposed crystal. Many papers have been written and several theories have been put forward to explain exactly what changes take place when film is exposed. No explanation is completely satisfactory.

A proposed scheme is represented in Figure 4-2, which shows one idea of how the process might work. For further ideas, you should consult one of the books listed on page 45.

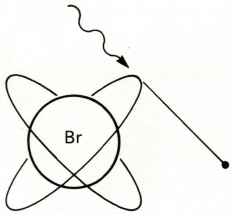
How can the latent image be stored in the emulsion? Consider that light is a form of electromagnetic wave and therefore a form of energy. When it strikes an ion in the emulsion, it can increase its energy and raise an electron in the ion to a higher energy level, and thus begins the formation of an image.

It is not known just how long an image will last. If the film is stored in a freezer, it shows no change. Even if it is stored under normal room conditions, an image may last many years. One student bought a 1909 box camera that still contained a roll of half-used film of the same era. The camera had lain in an attic for 60 years and had then been taken to a junk shop. The student bought the camera in 1970 for $2.00. When the film was taken out and developed, the negatives showed faint images. Although the prints of the negatives had very poor contrast, they showed horse-drawn vehicles and old-fashioned sleighs.

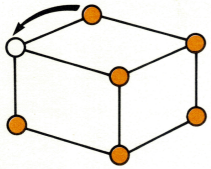
Find out the correct meaning of the words *fluorescence* and *phosphorescence* (see page 47). How can you make things fluoresce? In a darkened room, switch on an ultra-violet light. Shade your eyes from the direct rays, but bring near to the light source some anthracene, fluorescein, luminol, washing powder or some modern Canadian stamps.



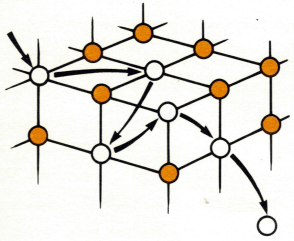
1. A Silver bromide crystal is made up of Ag^+ and Br^- ions in fixed positions in a crystal lattice.



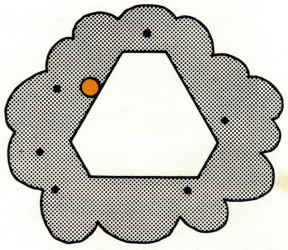
2. A quantum of light can provide enough energy to move an electron out of its orbital in a Br^- ion. The crystal then becomes conductive and the electron travels away from the Br atom, which remains.



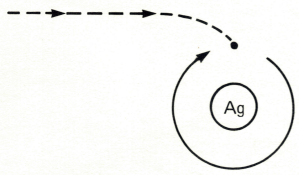
3. Because the Br atom that has lost the electron is surrounded by Ag^+ ions, it can only regain an electron by 'stealing' one from a neighbouring Br^- ion.



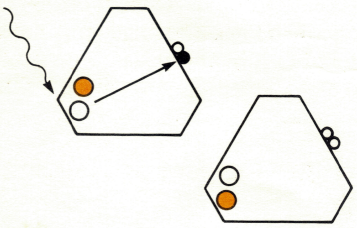
4. The 'positive hole' that results can move stepwise through the crystal until it reaches a surface.



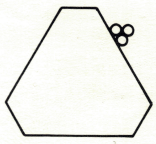
5. At a surface, the 'positive hole' disappears as an electron is transferred to the crystal from the surrounding gelatin.



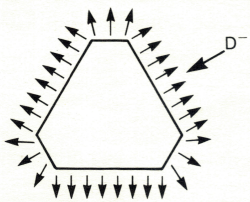
6. This electron, travelling through the crystal, may interact with an Ag^+ ion to form an Ag atom. This atom may then act as an attracting point for other silver ions.



7. Another quantum of light can free another electron from a site in the crystal. This electron may be attracted to an Ag^+ ion near the Ag atom in Step 6, to form a second Ag atom.



8. A third quantum of light can produce a third Ag atom. After many Ag atoms have formed, the crystal becomes susceptible to attack by ions in the developer.



9. 'Developability' is not fully understood, but it is thought that the group of silver atoms on the surface of the crystal represents a break in the electrostatic field that usually surrounds the crystal and that repels developer ions. Thus developer ions, which are negatively charged, can interact with Ag^+ ions. They donate electrons to them and change them to Ag atoms.

How do you process films for best results?

This question leads to a vast number of possibilities. You can try out different chemical substances in combination and in various concentrations. You can also vary the times and temperatures of processing. As a reference, you should try the D76 formula. This is the most widely used film developer, and the chemicals needed to make it are available from all the large manufacturers.

You will have some of the materials you need in school, and others are available from your local camera shop. By buying your own materials, you can mix developers that are no longer in production. You might not save much money by making your own developers, but you will learn more about them.

• *Activity 4.1*
Making D76 developer
(One period)

Measure out samples of the following materials, each of the correct mass.

Water	1000 cm^3	Sodium metaborate or borax	2 g
Hydroquinone	5 g	Sodium sulfite, anhydrous	100 g
Elon (metol)	2 g		

Pour 750 cm^3 of water at 30°C into a large beaker and add 2 g of sodium sulfite. Stir until the sodium sulfite is dissolved. While stirring continuously, add the metol and then the hydroquinone. After 2 minutes, add the borax and the rest of the sulfite. When the solids have dissolved completely, add the other 250 cm^3 of water. Store the solution in a glass bottle with a rubber stopper.

The solution can be used after diluting 1 part of developer with 3 parts of water (1:3 dilution). Development times for films of different speeds at 20°C are:

18 minutes for 400 ASA films (fast films)
14 minutes for 125 ASA films
12 minutes for 50 ASA films (slow films)

• *Experiment 4.1*
Developing a film (darkroom)
(One period)

For this experiment you will need a daylight developing tank, as shown in Figure 4-3. Read the instructions before using it. Take a length of waste film and practise loading it onto the reel with your eyes shut before you try to load the reel in the dark with the film you want to develop. Then load your film into the tank in a *completely dark* room. You can carry out the other steps in normal light. If you are using a 400 ASA film, it will take 18 minutes to develop. Most 135-size developing tanks hold 250 cm^3 of solution.

Save a 2-cm^3 sample of each solution from this experiment, both before and after its use, for testing in Experiment 4-2.

(1) Pour 63 cm^3 of D76 solution into a flask, and dilute it with water to a total of 250 cm^3.
(2) Adjust the temperature to 20°C ± 1°C.
(3) Pour the developer into the tank and tap the tank against the bench to dislodge any air bubbles. Start timing.

Figure 4-2 (left). This sequence of steps illustrates one theory to explain what happens when a silver bromide crystal interacts with a ray of light. A latent image is formed, which can be developed to make silver atoms.

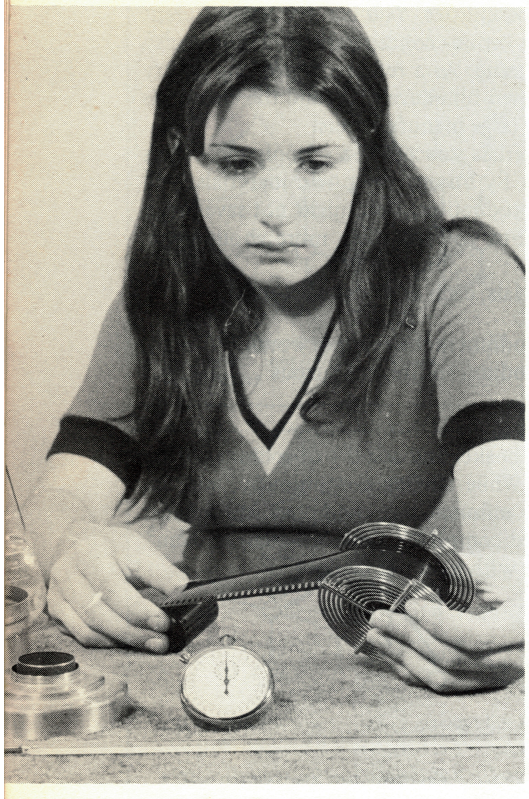


Figure 4-3. To develop your own negatives, the only equipment you need is a daylight tank, a thermometer, some measuring containers and a timing device. (Practice loading the reel with a length of scrap film.)

(4) Put the tank back on the bench and replace the cap.
(5) At the end of 1 minute, lift up the tank and slowly invert it twice. Place it back on the bench.
(6) Repeat the slow agitation once each minute.
(7) When 17.5 minutes have elapsed, pour out the developer and allow the tank to drain. The developer should be discarded.
(8) At the start of the 18th minute, fill the tank with water.
(9) Wait 5 seconds, pour out the water and repeat this washing.
(10) Now measure out 250 cm^3 of fixer and pour it into the tank.
(11) Start timing again.
(12) Fix the film for 2 minutes using rapid fixer, or 15 minutes for standard fixer. Again agitate once per minute.
(13) When the fixing time has elapsed, pour the fixer back into the bottle to be used again.
(14) Take the top off the tank. (You may examine the film to make sure that it is properly fixed. If it is, the edges of the film will be perfectly clear, with no trace of milkiness. If this is not so, replace the film in the fixer for the same length of time as before.)
(15) Place the tank under cold running water for 15 minutes to wash away all the fixer.
(16) Soak the film for 5 minutes in a solution of 1 drop of liquid detergent in 250 cm^3 of water.
(17) Hang the film to dry, with a clothes peg at each end.

Why do you need to agitate the film during development? (Remember that an oxidation-reduction reaction takes place whenever a latent image is being developed, and that the developer is a dilute solution of a reducing agent.)

Why is agitation not necessary during fixing?

You should be able to explain why this process produces *negatives* – that is, why an image of a person with dark hair, wearing a white laboratory coat appears to have white hair and a black coat.

You can now use these negatives to make prints as you did in Experiment 2.5.

• *Experiment 4.2 Investigating pH changes (Half period)*

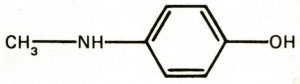
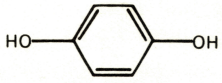
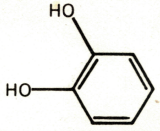
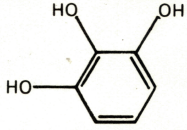
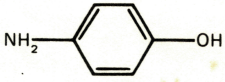
Take 2-cm^3 samples of fresh developer, used developer, wash water, fresh fixer and used fixer from Experiment 4.1. Test each with Universal Indicator or a pH meter. Write down the pH value of each solution. Why are these values necessary for the correct processing of negatives. (Look back to page 5.)

Why is dilute acid rather than water used as a stop bath in making prints? (See page 7.) Remember that developer ions are negatively charged and that acids contain hydronium ions.

What other substances are used to develop negatives?

Table 4-1 gives the chemical name, common name and formula of some of the many compounds used as developing agents.

Table 4-1 SUBSTANCES COMMONLY USED AS DEVELOPING AGENTS

IUPAC name	Common name	Formula
4-methylaminophenol	Metol, Elon	
1,4-dihydroxybenzene	Hydroquinone	
1,2-dihydroxybenzene	Pyochatechin or catechol	
1,2,3-trihydroxybenzene	Pyrogallol	
4-aminophenol	Kodelon, Rodinal	

Developers also contain three other types of substance:
(1) an alkali, which keeps the pH between 9 and 12;
(2) a restrainer, usually potassium bromide, to prevent development of the unexposed silver bromide, that would otherwise fog the negative;
(3) a preservative, usually sodium sulfite, which prevents oxidation of the developing agent.

Formulas for seven developing solutions that contain some of these materials are given in Table 4-2.

Here are some questions related to the components of the developers in Table 4-2.

(1) Notice that the developer which produces the greatest contrast (D8) contains the strongest alkali (sodium hydroxide). What is a

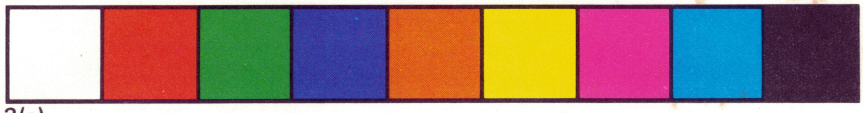
TWO BASIC METHODS OF PRODUCING COLOURED PHOTOGRAPHIC IMAGES:

1. Additive mixing of coloured beams of light: (i) red + blue = magenta; (ii) blue + green = cyan; (iii) red + green = yellow; (iv) red + blue + green = white.
2. (a) and (b) are reproductions of the cover of this book and the transparency from which it was made. The darker parts of the transparency become the lighter parts of the cover. Thus a positive becomes a negative: the tones are reversed. Also, each area of colour in the transparency becomes its complementary colour on the cover.
3. How a colour transparency works. (a) Suppose that the original subject is a series of coloured blocks.

1

2(a)

(b)



3(a)

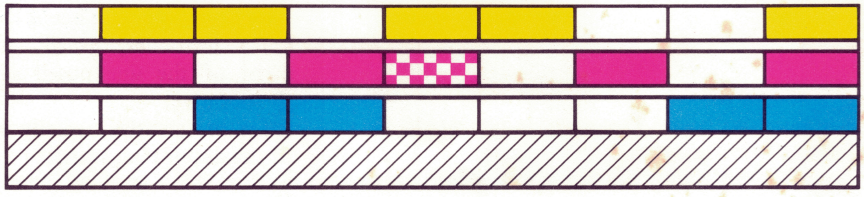
(b) When the film is exposed, a latent negative image of each colour forms, recorded at different intensities in the three layers. Development then turns these images into silver.

(b)

(c) Re-exposure and colour development produce a positive silver image and layers of dye molecules.

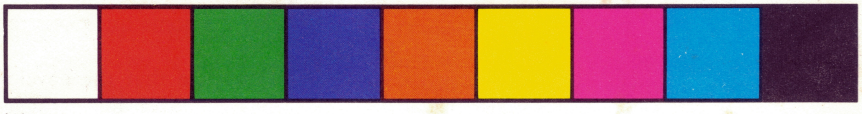
(c)

(d) Bleaching and fixing remove the silver and the dye molecule fragments that were not used.



(d)

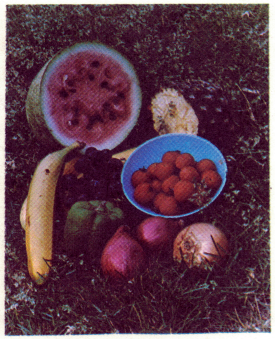
(e) Light passing through the layers of dye reproduces the original image almost exactly. There are always very slight differences in the colours of the original and the slide.



(e)

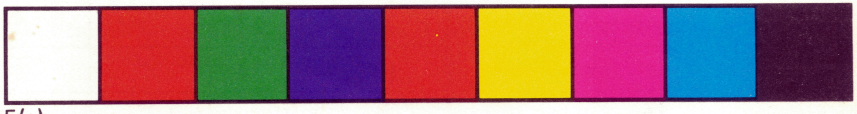
4. (a) is a colour negative and (b) a print made from it. The orange colour applied over the whole negative is known as a 'mask', to prevent light from passing through from one colour-sensitive layer to another.

4(a)



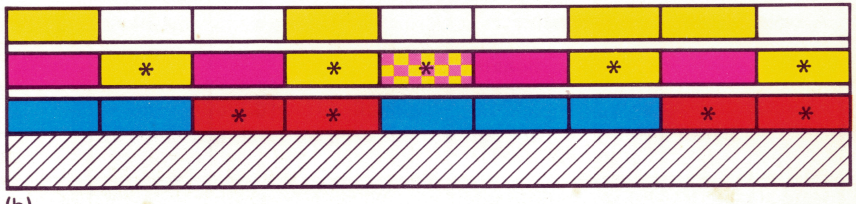
(b)

5. How colour prints are made.
(a) Suppose that the original subject is a series of coloured blocks.



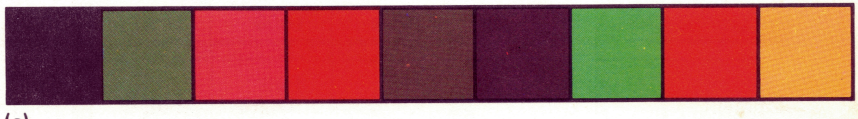
5(a)

*(b) Exposure and development of the film produce a negative. Tones and colours are reversed. The layers still contain colour coupler molecules, shown by *.*



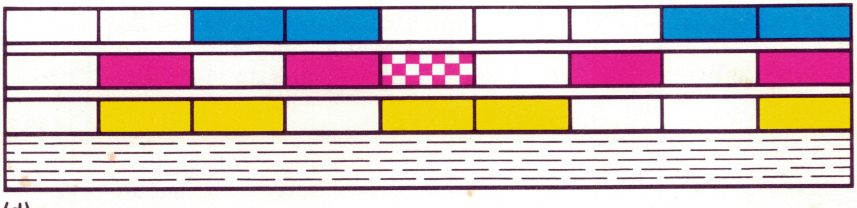
(b)

(c) The colours of the negative look like this when viewed. The orange colour at the right-hand end is a dye built into the film. It covers all parts of the image.



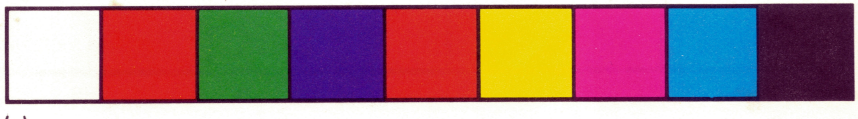
(c)

(d) The negative is projected onto the colour-sensitive emulsion on the paper, which forms three layers of dyes when developed. Bleaching removes the silver and leaves only the dyes.



(d)

(e) The dyes reproduce the appearance of the original subject. Notice that the colours and tones are both reversed in going from the negative to the positive.



(e)

buffer? Why do the other developers contain a greater concentration of a weaker alkali, such as sodium carbonate?

(2) If a film being developed releases bromide ions into the solution, why does potassium bromide in the developer have a restraining action?

(3) How does the sodium sulfite act as a preservative? Add a few drops of 10 per cent sodium sulfite solution to acidified potassium manganate(VII) and acidified potassium dichromate(VI) solutions, which are strong oxidizing agents.

Table 4-2 FORMULAS AND USES OF SEVEN DEVELOPERS

		Universal	DK50	D23	D76	D72	D163	D8
Reducing agent (g)	Metol		2.5	7.5	2	3.1	2.2	
	Hydroquinone	12	2.5		5	12	17	45
	Phenidone	0.5						
Alkali (g)	Sodium sulphite	50	30	100	100	90	150	90
	Sodium carbonate	60				180	175	
	Sodium metaborate		10		2			
	Sodium hydroxide							37.5
Restrainer (g)	Potassium bromide	2	0.5			1.9	2.8	30
Solvent (cm^3)	Water	1000	1000	1000	1000	1000	1000	1000
Dish development	Dilution	1:3	Full strength	Full strength	Full strength	1:1	1:2	1:2
	Time (min)	2 to 4	4 to 8	10	4 to 8	4	2	2
Tank development	Dilution	1:7	Full strength	Full strength	Full strength	1:1	1:5	1:2
	Time (min)	4 to 8	5 to 10	12	5 to 10	5	10 to 15	2
Recommended use.			High-speed films	High-contrast subjects	Most useful developer for films	General purpose also in intensifying and reducing	Warm tones on paper.	Produces maximum contrast. Use on lith film

• *Experiment 4.3 Making and using a compensating developer (One period)*

This formula for a compensating developer has many advantages. It can be used for all types of film; it can be used with wide variations of time and temperature; it keeps indefinitely and it is extremely economical. Make up solutions as follows:

Solution A:		Solution B:	
Metol	5 g	Sodium metaborate	10 g
Sodium sulfite	100 g	Water	1 000 cm^3
Water	1 000 cm^3		

The developer was first produced by Heinrich Stockler in 1939. It uses two solutions. One contains a reducing agent and a preservative; the other contains an alkali.

The 'compensating' effect is plain if you take photographs of a scene with extreme contrast. The developer will tend to reduce the intensity of the highlights and increase the intensity in the shadows. It will do this because the development is carried out in two stages. Load the film into your tank in a darkroom, as in Experiment 4.1.

(1) Immerse the film in solution A, which contains metol, for about 3 to 5 minutes. The emulsion absorbs metol, which starts to reduce the silver bromide in the highlights. The shadows are hardly affected. Return the solution to the bottle.

(2) Without rinsing, treat the film with the alkaline solution B for about 3 minutes. The highlights develop very rapidly, but cannot become too dark, because there is not sufficient metol to reduce this part of the negative any further. There is excess metol in the shadow part of the emulsion. Because its action has been accelerated by the alkali, it increases the intensity in the shadows and also gives a gain in contrast within the shadows. Pour the solution back into the stock bottle after you have used it.

Fix, wash and dry your film as in Experiment 4.1.

The concentrations in solution A of the developer are such that the film absorbs both components in the proportion 1:20. Therefore, the *composition* of the solution stays the same for as long as it is used. Its quantity merely decreases by the volume that is absorbed into the film. Thus the solution can be used over and over again. The solutions will keep for at least one year in stoppered bottles, although they may require occasional filtration after repeated use.

A compensating developer similar to that above is marketed as Diafine.

5 Altering photographic images

It is often necessary to modify the images you have produced, either as negatives or on paper. There are two main reasons for this.

(1) In making your negatives you may have made some error either in exposure or in development.
(2) You may decide to change the colours of your prints from black and white, for greater 'effect'.

This chapter describes chemical methods for carrying out three types of modification:

(1) intensification of negatives that are not sufficiently dense;
(2) reduction of negatives which are too dense;
(3) toning of prints.

All of the methods can be carried out under normal lighting conditions. You should first try the effect of the processes on images which you do not wish to keep. You can then confidently treat your more important pictures.

Before you try to correct faults in negatives, you should realize that best results come from correctly processed negatives. It may be preferable to re-take your photographs on a new roll of film. However, your pictures may have been taken at a school game for instance, and it would be impossible to re-take them. In that case, a picture with slight faults is better than no picture at all.

Figure 5-1. Negatives with faults. (a) Excessive contrast caused by over-development. Compare this with Figure 7-1. (b) Insufficient contrast, which is the result of too little exposure. (c) Scratches from careless handling, and uneven processing caused by buckling of the film while loading it on the reel. (d) Drying marks. These may be prevented by using a drop of detergent in the final rinse.

Underdeveloped negatives

By immersing the negatives in a solution which contains ions of another heavy metal, you can deposit atoms of this second metal on the atoms of silver which make up your image. This will leave the clearer parts of the negative almost unchanged, but will increase the density of the darker parts. By using this method, you will increase the contrast in your negative and correct the results of under-development.

• *Experiment 5.1 Correcting underdeveloped negatives (One period)*

Two metals you can use for this process are copper and uranium. Caution: all solutions containing heavy metals are poisonous.

(1) Copper intensifier

Solution A:		Solution B:	
Copper(II) sulfate	10 g	Potassium iodide	10 g
Ethanoic (acetic) acid (conc.)	56 g	Ammonia (concentrated)	50 cm^3
Water	1 000 cm^3	Water	500 cm^3

Mix A and B in the ratio 2:1 before use. Immerse the negatives in this solution until they do not fade any further. Wash the negatives for 5 minutes in running water. Then immerse them in a dish of 5 per cent solution of silver nitrate in distilled water, and agitate gently. The darkening will take place in 2 to 5 minutes. Inspect your negatives and stop the process when the lack of contrast has been corrected. Rinse the negatives and dry them, as you did after fixing in Experiment 4.1.

What is the final colour of your negatives? Take them into the darkroom and make a print from this strip of film. Compare the print to one made from an untreated film. To what extent has the contrast been improved?

(2) Uranium intensifier

Solution A:		Solution B:	
Uranium nitrate	100 g	Potassium hexacyanoferrate(III)	
Water	1 000 cm^3	(potassium ferricyanide)	25 g
		Water	1 000 cm^3

Use the same method as for copper, this time mixing A, B, and pure ethanoic acid in the ratio 4:4:1. Immerse the negatives in this solution until they are a uniform cream colour. Then rinse them thoroughly with water and immerse them in solution C:

Solution C:		
Concentrated ammonia	30 cm^3	
Water	1 000 cm^3	

What colour do the negatives turn?

Underexposed negatives

Of course, if parts of the negatives are completely clear, they had so little exposure that when you fixed the film, you removed all the silver bromide. You cannot correct this.

However, the parts of the film that were partially exposed still have some silver after development. You can treat this with an oxidizing agent to change the silver atoms to silver ions. Suitable oxidizing agents are manganate (VII) or dichromate (VI) solutions. If you carry out this process under room light, the silver ions will be exposed to light as they form. All you have to do then is rinse the film and place it in a developer such as D72 (Table 4-2) for about 5 minutes until the silver ions become silver atoms again.

• *Experiment 5.2*
Improving underexposed negatives (part in darkroom)
(One period)

Chromium intensifier stock solution	
Potassium dichromate(VI)	90 g
Concentrated hydrochloric acid	65 cm^3
Water	100 cm^3

Make up this solution and dilute 25 cm^3 to 250 cm^3 with water before use.

Cut a strip of negatives in half. Immerse one half in the diluted intensifier until it does not show any further change. Rinse for 2 minutes in running water. Then place the strip in D72 developer until maximum intensity is achieved. Rinse, fix, wash, and dry the strip. What changes have occurred? Now take the negatives into the darkroom and make a print from the intensified strip, and one from the untreated strip. Compare them.

Toning prints

By doing Experiment 5.3, you will alter the tones of some prints you made in Experiments 2.4 and 2.5. Use prints or test strips that are of no great importance so that you can see the effect of your solutions before trying them on important pictures. Often a picture which is not striking in the original tones may be most impressive after some other treatment.

If you have any old photographs to copy, as in Experiment 2.5, then it is very easy to turn the pictures into brown tones by the sulfide process. This will make them look as though they were produced a long time ago.

Most of the treatments listed from this point to page 30 involve chemical changes similar to those in the intensification procedures of Experiment 5.1.

Iron(III) ammonium citrate is used in making blueprints. If you have tested for nickel, using butanedione dioxime (dimethylglyoxime) in an analysis experiment (see *Action Chemistry*, page 115), you will understand how the second stage of the red toning works.

Try to write an account of the chemical changes that occur during the following procedures.

• *Experiment 5.3*
Using toning solutions
(Two periods)

You can make blueprint paper by mixing 10 cm^3 of a 20 per cent solution of potassium hexacyanoferrate(III) (potassium ferricyanide) with 10 cm^3 of a 25 per cent solution of iron(III) ammonium citrate in a darkened room, then brushing it on a piece of paper and allowing it to dry. You can then use it as in Experiment 2.4 with exposure times of 5 to 10 minutes. The paper is washed in running water to produce the image.

Make up solutions as follows and label the flasks in which you store them.

(1) Copper toning solution

Copper(II) sulfate	10 g
Potassium hexacyanoferrate(III)	20 g
Ammonium carbonate	10 g
Water	1 000 cm^3

(2) Blue toning solution

Solution A:		Solution B:	
Potassium hexacyanoferrate(III)	20 g	Iron(III) chloride	10 g
Ammonium carbonate	210 g	Hydrochloric acid	85 cm^3
Water	1 000 cm^3	Water	1 000 cm^3

(3) Sulfide toning solution

Solution A:		Solution B:	
Potassium bromide	50 g	Ammonium sulfide	30 cm^3
Potassium hexacyanoferrate(III)	100 g	Water	1 000 cm^3
Water	1 000 cm^3		

(4) Red toning solution

Solution A1:		Solution A2:	
Nickel(II) nitrate	50 g	Potassium hexacyanoferrate(III)	40 g
Potassium citrate	150 g	Water	1 000 cm^3

Mix solution A1 in one flask and solution A2 in a second flask. To make solution A, mix equal volumes of the two solutions *just before use*, and add a few drops of dilute nitric acid.

Solution B:

Butanedione dioxime (dimethylglyoxime) (saturated solution in methanol)	40 cm^3
Sodium hydroxide (0.1 $mol \cdot dm^{-3}$ solution)	100 cm^3
Water	860 cm^3

Just before use, add a few drops of concentrated ammonia solution.

If the toning process takes place in one step, simply soak your print in the solution until there is no further change. Then remove the print and rinse it for several minutes in water before you dry it.

For toning methods requiring two solutions, place the print in solution A until the image is completely bleached out. Wash the print in running water to remove all yellow stain. After this, soak the print in solution B until the colour change is complete. Remove the paper, rinse it, and dry it as before.

Can you explain all the chemical changes? You may be able to confirm your explanations by carrying out investigations in test tubes. For instance, prepare some silver chloride in a test tube, according to the method described in Experiment 2.3. Add some 0.1 per cent sodium sulfide solution. What colour change occurs? Can you complete the following equations?

silver chloride + sodium sulfide ⟶ ▬ + ▬

$AgCl + Na_2S \longrightarrow$ ▬ + ▬

Reduction processes

Reduction processes are used in three ways:

(1) for reducing prints;
(2) for reducing negatives that are overexposed;
(3) for reducing negatives that are overdeveloped.

In each case, some silver is removed from the image so that it becomes lighter. The same solution is used for (1) and (2). It is called 'Farmer's reducer', after its originator, Howard Farmer. It will remove silver from the lighter parts of the image more readily than from the darker parts. Thus it can be used to 'brighten' the highlights of a print or to increase the contrast of an overexposed negative.

• *Experiment 5.4*
Making Farmer's reducer
(Half period)

Make up two solutions as follows:

Solution A:		Solution B:	
Sodium thiosulfate	125 g	Potassium hexacyano-ferrate(III)	100 g
Water	100 cm^3	Water	1 000 cm^3

Mix 1 cm^3 of A with 10 cm^3 of B. Use the solution within 2 minutes of mixing.

Apply the solution to a print with a Q-tip or immerse a negative in a dish. Wait 1 minute and then rinse away the solution. Do you see any effect? If there has been insufficient change, mix another sample and reapply it to your image. Can you explain the chemistry of the process? (Remember: (a) the hexacyanoferrate(III) ion is an oxidizing agent: it can accept electrons easily; (b) the thiosulfate ion readily combines with silver ions but not with silver atoms.)

With a little practice on some scrap prints, you will be able to use this reducer to improve your pictures. For example, with a cotton swab, apply dilute reducer to the clouds in a landscape. You can also brighten the eyes and teeth of a portrait subject, using a fine paint brush. Wash all prints or negatives that have been reduced before drying and using them.

For processing overdeveloped negatives, you will need a solution that dissolves the denser parts of the image more rapidly than the lighter parts. Such a one is a dilute acidified solution of iron(III) sulfate. However, a more reliable method is to bleach the image by oxidizing it to silver bromide and then redevelop the image to the required contrast using a 20 per cent solution of a developer such as D76. A suitable bleaching solution consists of 0.2 g of potassium dichromate(VI), 1 cm^3 of concentrated hydrochloric acid, and 60 cm^3 of water. Be careful not to spill any of the acid.

Immerse the negative in this solution. When no further change occurs, rinse the film. Then treat it with the dilute developer. Watch the process take place until the contrast is correct. Rinse the negative, fix and wash it as in Experiment 4.1.

6 Making transparencies

Monochrome transparences

In this chapter you will find out how to make two types of transparency: colour slides and monochrome slides. There are photographic principles common to each, but you can make monochrome (black-and-white) slides for 15 per cent of the cost of colour slides. You will be able to make your own solutions, and understand their chemistry. Any mistake you make will be less costly. (Since you can make and mount monochrome slides for about 5 cents each, you may find that you can help other students with projects that require visual material.) When you have confidence in your exposure and processing techniques, you should carry out Experiment 6.2 so that you will gain some ideas of how coloured images form.

Making a positive image is a three-step process. First, the film is exposed and developed to give a negative silver image. This silver image is then bleached out, and the unused silver bromide is left behind. The final stage is the re-exposure and redevelopment of the film to turn this silver bromide to silver, thus creating a positive image of the original scene. (Figure 6-1 will help you understand these steps.)

You will already be familiar with the chemistry of many of the steps, but their order will probably be unfamiliar. The following solutions are required:

(a) a dilute paper *developer* with a little thiosulfate added to keep the highlights clear of any slight silver deposit;
(b) a *fixer* that must not contain any ammonium ions, or it will destroy the emulsion. For this reason you cannot use rapid fixer;
(c) an *oxidizing solution* to act as a bleach;
(d) a *clearing solution* to remove any stains produced by the bleach. (Potassium manganate(VII) causes stains by forming manganese(IV) oxide. These can be removed by any solution containing sulfite ions and excess hydronium ions.)

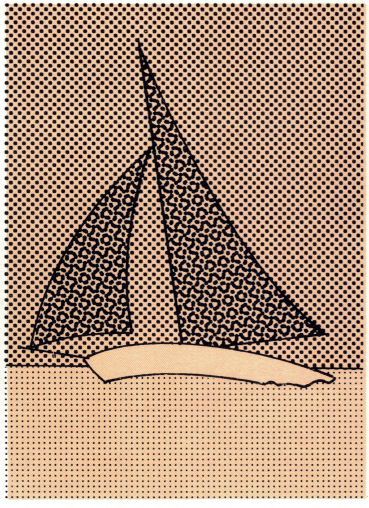
When exposing the film for monochrome transparencies, remember that this is a positive-negative-positive process carried out on one piece of emulsion. What will happen if you overexpose the film in your camera and then carry out the process illustrated in Figure 6-1?

The range of brightness of reflected light coming from a print, from its brightest highlights to its darkest shadows, is about 40:1. The range of brightness in an outdoor scene may be 1 000:1. By making transparencies and viewing them by transmitted light, you can see the full 1 000:1 range. Even when a slide is projected on a screen, you may be able to see a 250:1 brightness range. Therefore your pictures will be much more brilliant if they are produced as slides rather than as prints. Remember this when exposing film in your camera, so that you can take advantage of all the possibilities for creating pictorial effect.

This process can be carried out using any brand of film, but the solutions in the Ilford method are easiest to make up.

1. Original scene

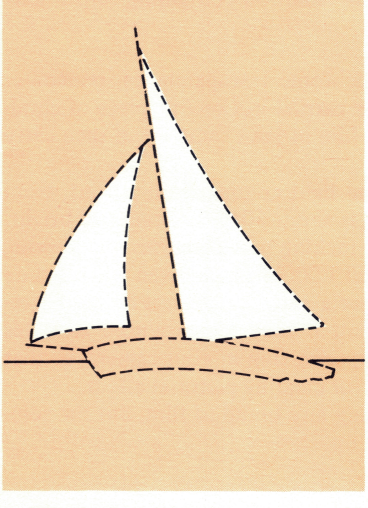
2. Film after first exposure



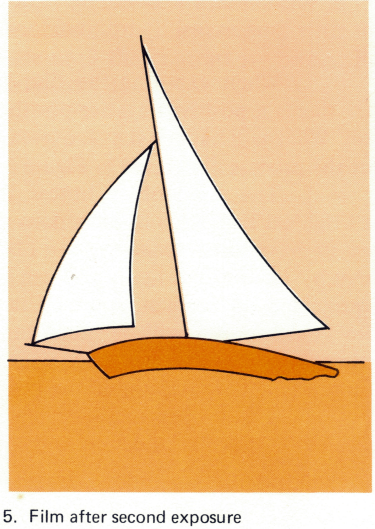
3. Film after first development

The orange colour represents the latent image.

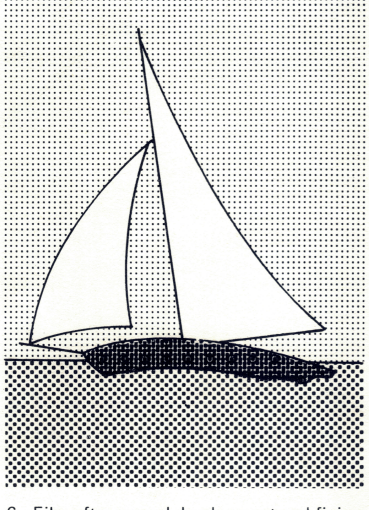
The black dots represent the silver.



4. Film after bleaching



5. Film after second exposure



6. Film after second development and fixing

• *Experiment 6.1*
Making monochrome transparencies (part in darkroom) (Two periods)

Take pictures on a roll of Ilford film (HP4, FP4, or Pan F). Expose the film exactly as the manufacturer recommends. Make up solutions in water as formulated below. Using a water bath, adjust the temperature of each solution to 20°C.

Developer: Ilford Bromophen diluted 1:3 with water, with sodium thiosulfate added as follows: for FP4, 12 g per 1000 cm^3 of solution; for all other films, 8 g per 1000 cm^3.

Bleach A: Potassium manganate(VII): 4 g per 1000 cm^3 water.

Bleach B: Concentrated sulfuric acid: 20 cm^3 per 1000 cm^3 water. (Take care when diluting this acid; ask your teacher for help.)

Just before use, mix equal volumes of A and B to make enough solution to cover your film.

Clearing bath: Sodium or potassium disulfate(IV) (metabisulfite): 25 g per 1000 cm^3 water.

Fixer: Any standard acid fixer (*not* rapid fixer).

Processing is the same for all films. Steps (2) to (14) must be done without interruption.

(1) Load your film into the tank in a completely dark room. After this step you may use normal room light.
(2) Pour in the developer and agitate the tank for 5 seconds.
(3) Stand the tank on the bench and leave it for 25 seconds.
(4) Agitate for another 5 seconds.
(5) Repeat steps (3) and (4) for 11.5 minutes.
(6) As soon as 12 minutes have elapsed, pour the developer into a clean flask. You will need the developer again in step (13).
(7) Wash the film with running water for 3 minutes.
(8) Add the bleach and agitate for 3 minutes.
(9) Discard the bleach, take the lid off the tank, and wash for 3 minutes in running water.
(10) Add the clearing bath. Allow the film to soak for 2 minutes and then pour the solution back into the bottle.
(11) Wash the film for 2 minutes in running water.
(12) Take the film off its spiral and hold it in front of a bright light source, such as a sunlit window or a projector. Make sure each part of the film receives 30 seconds of exposure on each side. Rewind the film onto the spool.
(13) Add the developer from step (6) and develop for 6 minutes, using the same agitation method as before. Discard the developer.
(14) Wash for 2 minutes in running water.
(15) Add the fixer for 10 minutes. Pour it back into the bottle.
(16) Wash the film in running water for 30 minutes. Dry it as you have done before.
(17) Mount your transparencies in plastic or cardboard frames and project them.

Figure 6-1 (opposite page). These illustrations represent the changes that take place in the emulsion as you carry out the reversal processing.
Step 1. *The original scene contains four areas of different tone – sea, sky, sails, and hull.*
Step 2. *Dark tones produce little latent image.*
Step 3. *As a result, little silver is produced on development. Light tones give greater intensity, first in the latent image and then in the silver.*
Step 4. *Bleaching removes the silver, leaving the silver bromide unchanged.*
Step 5. *The re-exposure gives an intense latent image where there is a larger amount of silver bromide remaining; that is, in the hull.*
Step 6. *When redeveloped, the silver bromide becomes a very dark patch of silver. Since most of the original silver has been removed from the area of the sails, there is little silver bromide remaining so that re-exposure leaves little latent image. Redevelopment can produce very little silver, so that the tone of the sails is very light in the final transparency.*
Can you summarize the chemical *changes that occur in this process? Do you think that your transparencies could be toned, using methods from Chapter 5?*

Colour photography

Kodak Infra-Red Aero film can be used in survey operations. Look in a geography or science book for examples of how aerial infra-red photography is used to determine whether crops are healthy or not.

All colour film is based on monochrome film. Silver halides are used to form a latent image which is developed in the usual way. However, colour film has layers of materials on top of the silver bromide emulsion. These are sensitive to different wavelengths of light and form coloured compounds from the substances produced during development.

If you have never made any dyes before, look up *diazo compounds* in an organic chemistry text. Perform the experiments on pages 172 and 173 of *Action Chemistry* in this series.

In colour film, there are three layers of colour-sensitive material. Each layer is affected by one part of the visible spectrum. When the latent image in the silver layer is developed, molecules diffuse into the colour layers. Then the 'colour developer' is allowed to react with the film. It produces reactions of the type shown in Figure 6-2. These resemble other diazo coupling reactions you have studied. Although the principle is not a complex one, extensive research is required to select the materials and conditions for the reaction, so that the colours in an original scene can be reproduced accurately in the transparency.

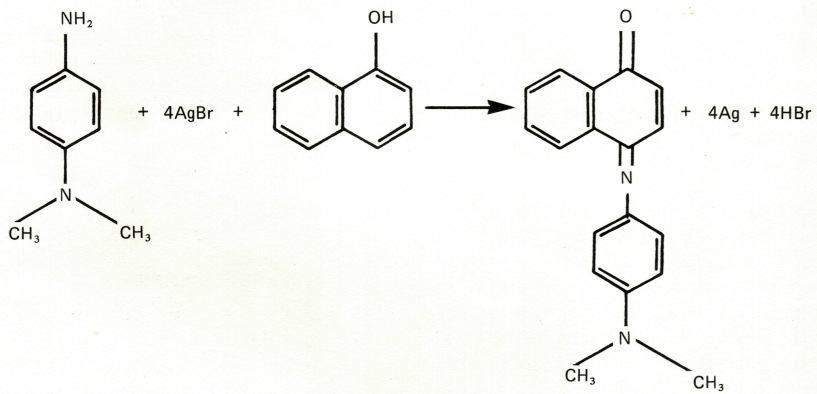


Figure 6-2. A diazo coupling reaction in colour development.

(You might find it interesting to read how Kodachrome film was first produced. The research was carried out with simple equipment by two amateur photographers who were, in fact, professional musicians.)

To process colour transparency film yourself requires careful control of temperature, time, and the concentration of the solution. You may recall from your study of chemical kinetics that these three factors govern the rate of a chemical reaction. If you are to control the colour-producing reaction, you must carry out precisely the development of the silver bromide latent image so that the correct concentrations of materials are produced to start the coupling reaction. This step also governs the overall intensity of the colour image.

By carrying out the colour development under controlled conditions of time and temperature, you can be sure that the balance between the three colour layers is correct. If this is not so, your slides may have a 'colour cast': that is, they may have a predominance of one of the three colour layers. (Often this is caused by temperature change, rather than by errors in timing or concentration. If the developer temperature is too low, the images may have a blue cast. Too high a temperature in the developer may cause a pink cast.)

• *Experiment 6.2 Developing colour transparencies (darkroom) (Two periods)*

Choose any type of film other than Kodachrome and expose it exactly as recommended by the manufacturer. (Kodachrome film cannot be processed except at the manufacturer's plant where the colour-producing substances are added as the film passes through the processing machine.) Select a kit of chemicals for processing your film. These are available from the several manufacturers. Each has its own advantages.

(a) Kodak makes a greater number of different types of film that can be processed with their kit than any other company, and publishes a leaflet, *ESP 1*, which gives instructions for using film under special lighting conditions.
(b) The Ansco kit is small and less costly. The processing temperature is 20°C. This is fairly easy to maintain in a school laboratory.
(c) The Unichrome kit contains only liquids. These are simpler and more economical to use than dry substances. In addition, this type of kit can be used to process films from manufacturers such as Agfa and Fuji who do not market developing kits for use by amateurs.

Make up the solutions and dilute them according to the instruction sheet, and process the film using the directions supplied with the kit. Pay attention to temperature control of the two developers. The manufacturers recommend no greater variation than ±0.25°C. This can be done by keeping the flasks of developer in a large volume of water which acts as a heat sink.

In processing any film by this method, you may remove the lid from the tank after the first stop bath stage. You can then watch what happens to your film during each of the later stages and record your observations.

When you can confidently carry out the processing of film exposed normally, read the maker's instructions for 'push-processing' the film to higher-than-normal film speed. By this method, films normally rated at 400 ASA can be exposed at 800 ASA or 1000 ASA and still be processed to give good quality slides. Using this procedure, you can develop photographs taken without flash in a concert hall or during a school play or at a hockey game. (You can also use these films in a classroom or laboratory which has fluorescent lighting; but there may be a colour cast produced, depending on what type of fluorescent tubes are in use.)

7

Adventures in photography

Topic 1: Close-up photography

This chapter includes suggestions for a number of interesting projects. Some require special skills in machining or electronics. In the books listed on page 45 you will find other ideas to try.

To begin the investigation, all you need is a #3 supplementary lens to fit your camera. This is an extra lens which fits over your standard lens and modifies its focusing distance. The scale of distances inscribed on your lens will no longer apply. There are three ways , however, to focus your image.

(1) For a reflex camera, you may focus by eye.

(2) You may follow the table of focusing distances provided by the manufacturer of the supplementary lens.

(3) You may open the back of your camera, and fasten a piece of tissue across the opening through which the light travels. Make sure that the image is sharp and that it is framed correctly. Remove the paper without moving the camera and insert the film on which you are making the exposure. (See Figure 7-1.) The fish in Figure 3-7 was photographed using this technique.

When you expose the film, be sure to use a lens opening smaller than f4 and a tripod to help to hold the camera steady. Since supplementary lenses are not expensive, their optical quality may not be satisfactory if used at large apertures. (Using small apertures gives greater depth of field, but this is not a disadvantage when photographing non-moving objects.) If you have a reflex camera, you may wish to buy a set of extension tubes or bellows and do more ambitious close-up work, including slide copying.

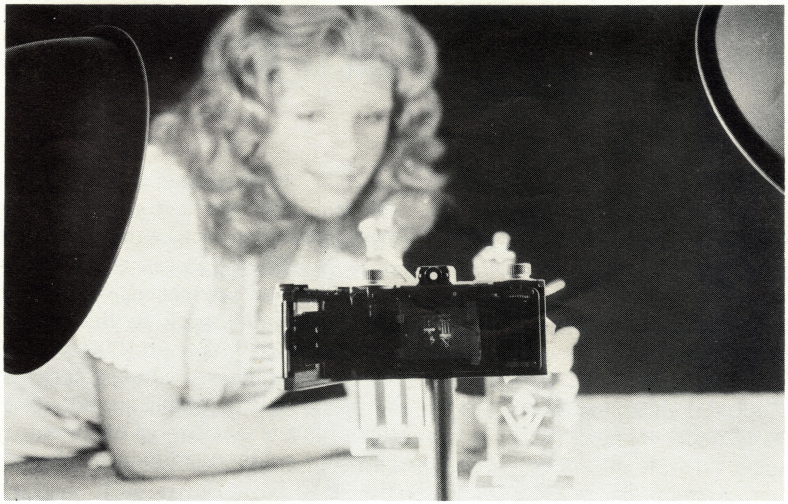


Figure 7-1. How to form an image of an object at a distance smaller than the minimum on the focusing scale of your camera. Tape some tissue across the film plane. Focus and frame the image, remove the tissue, and then load your camera without moving it.

Topic 2: Time exposures

The picture on the front cover of this book was taken using an exposure of 10 seconds. For further details about this photograph, see the caption in the margin of the copyright page, (p.ii).

The exposure is not always easy to determine in a situation like this, but you may either use Table 7-1 as a guide or 'bracket' the exposures by using a series of different times, such as 2 seconds, 5 seconds, 12 seconds or 30 seconds, so that there is a good chance that one of them will be satisfactory.

Table 7-1 CHART FOR SUBJECTS REQUIRING LONG EXPOSURES

Subject	Exposure for 64–80 ASA film	Exposure for 400 ASA film
Theatres, neon signs, large fires	1/30 s, f4	1/125 s, f8
T.V. pictures, campfire groups, store window displays	1/15 s, f2.8	1/30 s, f5.6
Ball games at night, bright interiors, firework displays	1/15 s, f2	1/30 s, f4
Floodlit fountains and buildings, Christmas trees, dim interiors	1 s, f4	1/15 s, f2.8
Illuminated waterfalls, skylines at night	15 s, f4	1 s, f5.6
Dimly lit streets, full-moon landscapes	1 min, f4	20 s, f8

This table has been adapted from a small part of The Jiffy Calculator for Night-light Exposures. The full calculator is available through Dorso Optics, Ltd., 5000 Buchan Street, Montreal, Qué.

Any moving object will record on film as a line or a blur when a slow shutter speed is used. Striking photographs of sports events or of waterfalls can be created using long exposures. You will have to make some trials to find the best effect. At night, a street scene or an exposure at a fairground will show only the paths of the bright light sources, such as the car lights, together with a sharp image of sources such as neon signs. You can make exposures like these using any camera mounted on a tripod, setting the shutter to B or T, and holding the shutter open with a cable release.

Figure 7-2 shows a modern version of a very simple device, the 'pinhole camera'. Older designs using shoeboxes and sheet film are slow to operate, since the camera may be loaded and unloaded only in the dark, one picture at a time. Using a 126 cartridge enables you to take 12 pictures without reloading.

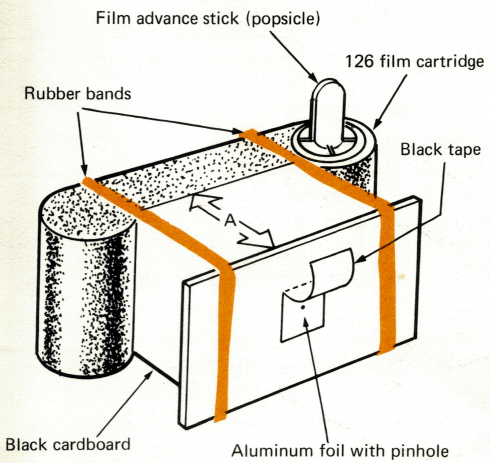


Figure 7-2. A pinhole 'camera' made from a 126 cartridge. What is the effect of changing the depth of the black cardboard attachment so that distance A is: (a) half that shown; (b) twice that shown?

Simply cover the pinhole with black tape, wind the film to frame 1 with the popsicle stick, then place the 'camera' on a tripod. Frame the picture and peel back the tape. Guess a suitable time interval, press the take back in place, and wind on to frame 2 with the popsicle stick.

Peterson's Photographic Magazine for February 1975 describes how to construct and use a pinhole camera which takes a 360° photograph.

Topic 3: Making an inexpensive fisheye lens

For any 35 mm camera which uses interchangeable lenses, a lens of 50 mm focal length will usually be the least expensive, since this is the standard focal length. More camera owners use this lens than any other. Many photographers have wide-angle lenses of focal length 28 mm or 35 mm and telephoto lenses of 135 mm, 200 mm, or perhaps 400 mm.

Beyond these limits, the number of lenses sold begins to decrease. Two possible reasons are:

(1) the lenses are difficult to make and therefore expensive;
(2) you would use such a lens less often since it would be needed only for special situations.

However, because of the visual effects these lenses make possible, they are a necessary part of a complete photography system such as might be shared by the staff of a newspaper.

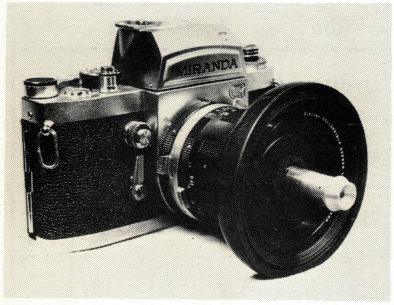


Figure 7-3. You can easily make a fisheye-type lens like this one.

It is not easy to construct a cheap substitute for a telephoto lens, but a satisfactory fisheye lens can be made from the lens and mount that fits in a front door of a home so that a caller may be recognized. You can buy one at a hardware store. When fitted to your camera, the lens will give a circular image, which covers approximately 180°. It can be focused by the normal lens of your camera.

The device is most easily used on a reflex camera, but it can be used on any camera with the tissue-paper technique of focusing outlined in (3) on page 36.

The easiest way to mount the lens on your camera is to use a spare lens cap. Measure the diameter of the thread at the rear of the door fitting. Drill a hole in the centre of your lens cap and thread the fitting through it. (Be sure your fitting cannot touch the front surface of your camera lens and scratch it.) Cement the fitting to the lens cap.

Test the approximate aperture of this lens by exposing some short lengths of trial film. As a guide the device will have an effective aperture of f5.6 to 8 when fitted to a lens of aperture f2. With an f4 lens the effective aperture will be f11 to 16. Figure 7-4 shows the kind of photograph that can be taken only by using a lens of extremely wide angle.

Figure 7-4. This type of photograph can be taken only by using a fisheye lens.

Topic 4: Photographing very small objects

The method described in Topic 1 cannot be used for objects much smaller than 1 cm across. If you wish to photograph a fly or a part from a watch, for instance, a special arrangement is needed. Normal camera lenses cannot be used since they give an image which is very sharp only when the ojbect is larger than the image. However you can use a simple trick to make high-quality images of small objects.

Consider the purpose of a movie camera lens. It is designed to give very sharp images of large objects (people and scenery) on a small piece of film (8 mm across). Look at Figure 7-5. For this topic, you will use a movie camera lens *in reverse*. Then you can take a very small object and make a large image of it on your film. By fitting it in a sliding mount, you can vary the magnification obtainable from your movie camera lens.

Where do you obtain your lens? If you go to a camera shop to buy it, tell the dealer how you intend to use the lens, and he may let you have a lens cheaply from his 'junk box'. If you visit a second-hand shop, or ask your relatives, you may be able to find a movie camera that is obsolete or even broken. This will be very inexpensive! Clean the lens carefully with a tissue and make sure that it has no scratches or loose glass parts. The condition of the rest of the camera does not matter, since you will not need it. Remove the lens and mount it in a hole which you have drilled in a piece of black plastic sheeting about 10 cm × 10 cm × 0.5 cm.

All manufacturers of 35 mm cameras with interchangeable lenses can provide a plastic 'body cap'. This is used to keep dust out of the camera when transporting it with the lens removed. Obtain one of these caps to fit your camera and remove the centre part, leaving a rim about 2 mm wide.

Cut a piece of black plastic drainpipe with the same outside diameter as your body cap and about 15 cm long. Cement the flat face of your cap firmly to the end of the pipe, so that you can fit the pipe onto your camera body. Now

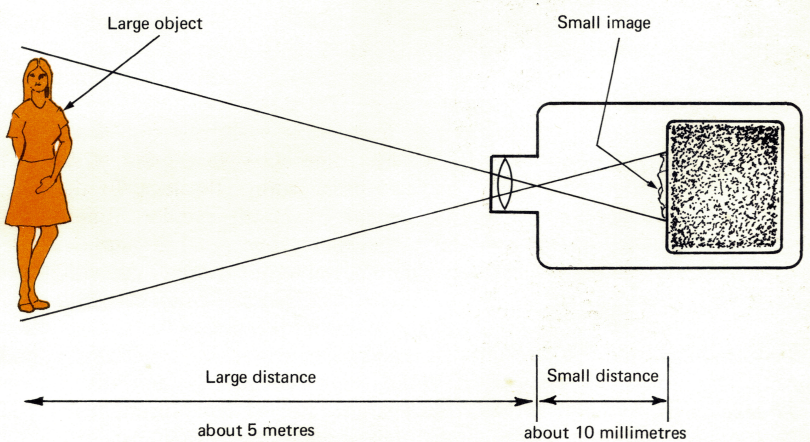


Figure 7-5. How a movie camera lens is normally used.

cut another piece of black plastic pipe about 15 cm long. It should be just large enough to slide inside the first piece of pipe. Cement your square lens board over the end of the narrower pipe so that the front of the lens faces in toward the camera. (You do not need to remove the excess plastic from the square sheet.)

You are now ready to use your arrangement. A suitable method is shown in Figure 7-6. Focus is adjusted by sliding the tube that holds the lens. Find the approximate focus position, then place black tape over the join. This will hold the tubes firmly together and prevent any light from entering. Any fine adjustment in the focusing is best made by moving the object rather than the lens or camera.

For illuminating the object, you can use two microscope lights, one on each side of the object.

This arrangement will take photographs of specimens as small as 2 mm across. For smaller objects than this, you will have to use a microscope.

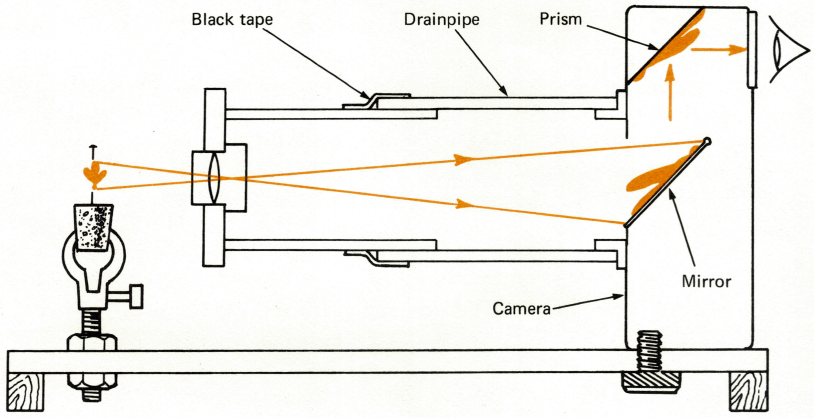


Figure 7-6. Using a movie camera lens in reverse.

Topic 5: Photomicrography

All comprehensive camera 'systems' have a microscope adapter. To use this adapter, remove the lens, fit the adapter to the camera body, and clamp the adapter over the eyepiece tube of the microscope. Then focus the image using the microscope controls and view the image directly through a reflex camera. For a non-reflex camera, you will have to use tissue paper, as in (3) on page 36.

If you cannot obtain an adapter, but have access to a machine shop, you could make an adapter yourself using a design like that in Figure 7-7. (T2 adapters are available for almost all makes of 35 mm camera.)

In making photomicrographs, why is it most important that the apparatus not vibrate during the exposure? There are two ways to minimize vibration.

Figure 7-7. Fit a T2 adapter onto your camera body. With a lathe, any piece of wood, metal, or black plastic can be made into a microscope adapter. Simply turn down an inside taper and an outside taper to fit the two diameters. Keep trying the adapter on the microscope and remove more material until the distance from the face of the camera to the eyepiece is correct, so that the image is sharply focused.

Figure 7-8. A photomicrograph of volvox algae taken at 180 × magnification using inexpensive equipment such as shown in Figure 7-7.

Topic 6: Polarization micrographs

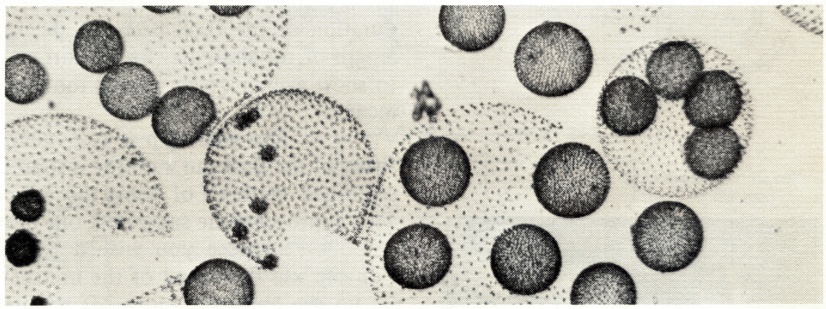
(1) Clamp the microscope firmly to the bench.
(2) Use a very intense light source so that your exposures are less than 1/100 second. You can do this by first focusing the microscope using the normal illumination system, then replacing the light by a beam of light from a projector. (Do not look down the microscope when this intense light is being used.)

The exposure time will depend not only on the type of film you use and how dark your subject is, but also on the magnification of the microscope lens you use. (Look at a microscope with a lens turret. Can you see why the intensity of the image decreases with magnification?)

If you have no metering system on your camera, use 100 × magnification, 400 ASA film, and 1/250 second as an approximate guide and as a basis for further experiment.

Figure 7-8 shows an example of the use of this technique.

If you want top quality results with low-contrast biology subjects, Kodak makes two special photomicrography films, a monochrome film and one for colour transparencies.



This method was used to produce the covers of *Action Chemistry* and *Chemistry of Man and Molecules*. It is chiefly used with colour film since this gives the most spectacular results.

Many materials affect polarized light. Although the effect cannot be seen with only one piece of polaroid, you can observe how the light rays are affected, by using a second piece of polaroid as an 'analyser'.

Place some pieces of broken plastic petri dish between two pieces of polaroid filter. Hold these over a small lamp and look down through them. The lower filter will then act as the polarizer and the upper as the analyser. Twist the analyser to obtain the best effect. This is often seen when the polaroids are 'crossed', that is, placed with their axes at 90° so that no light passes through the part where there is no perspex.

Place the polaroid filters on the stage of a microscope and use the technique of Topic 5 to take photographs of the plastic.

You can now take colour pictures of certain crystals as they grow. You can also take colour pictures of thin sections of certain rocks and minerals.

There are many substances of biological importance such as vitamins and drugs (including aspirin) that affect polarized light. However, some very common materials such as sodium carbonate and sodium thiosulfate can be used for this procedure. All you need to do is prepare a saturated solution of the substance, place a few drops on a microscope slide and spread them into a thin film. Wait for crystallization to begin; focus the microscope on the growing crystal boundary and release the shutter when there is a striking arrangement of shapes and colours.

Watch a single crystal carefully as it grows during one minute. What happens to its colour? How does this compare with the order of wavelengths in the electromagnetic spectrum? Can you suggest what change in the crystal causes this? For a further understanding of how polarized light interacts with crystals and solutions, you will have to consult a college text.

Topic 7: High-speed flash

Electronic flashguns are of two types, manual and automatic. The manual kind gives a flash of constant duration, about 1/800 second. The automatic type has a sensor which receives reflected light from the subject being photographed, measures it, and then switches off the flash when the illumination has been sufficient for a correct exposure. Thus, if you bring an object closer to the flashgun, the duration of the flash becomes shorter. When the object distance is 30 cm, the length of the flash may be as short as 1/50 000 second. You can use the flashgun to show events which change too rapidly to be seen or photographed by normal means.

The vital step is to synchronize the opening of the shutter and the firing of the flashgun with the instant at which an event takes place. Many of the published methods of doing this are complex. The following method is simple. Two approaches are suggested, one more sophisticated than the other.

Suppose you wished to photograph a hammer smashing an object. You can use the sound of the impact to trigger the flash by microphone. If you set up the apparatus, turn off the lights, open the camera shutter, smash the object and then close the shutter, the flash gun will create the image of one stage of the destruction!

By using sound as the trigger, you can choose whichever stage of the destruction you wish, simply by controlling the distance over which the sound travels. You do this by moving the microphone nearer to or further away from the hammer.

Two designs of trigger are given here. Both are based on the same system that is outlined in Figure 7-10.

In Figure 7-10(a), you can use common equipment, such as a tape recorder microphone and a record-player amplifier. The only piece of special equipment needed is the relay.

In Figure 7-10(b), the equipment is much smaller. It consists of a crystal microphone, an integrated circuit, and a solid state switch. (See Figure 7-11.) The chief advantage of this design is that it has a much shorter operating time than the larger equipment. The parts are not expensive. A suitable source is listed on page 46.

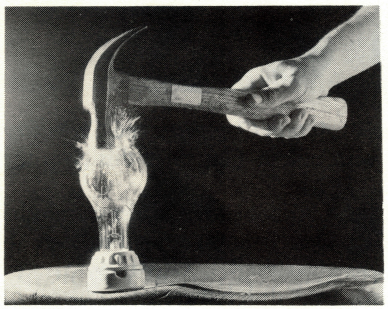
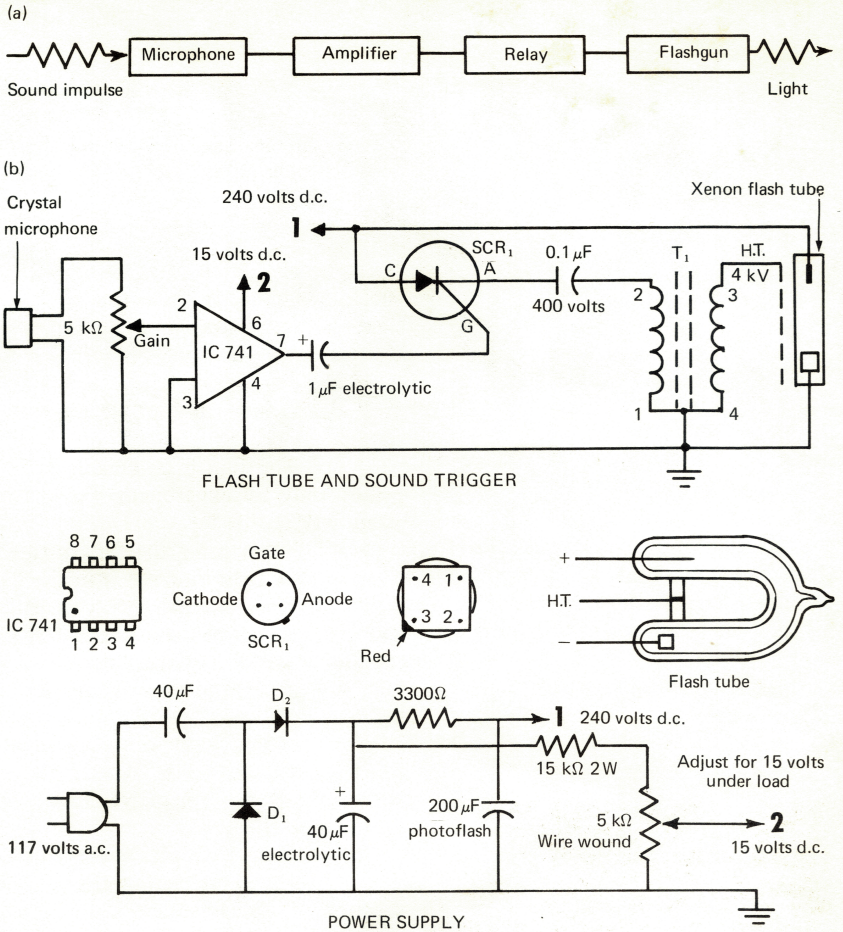


Figure 7-9. This picture was taken using the equipment shown in Figure 7-11 and a standard flash unit of about 1/800 second duration. With an automatic flash unit, you can 'freeze' even more rapid events. As the object is brought nearer to an automatic flash unit, the flash duration is shortened to less than 1/50 000 second.

Figure 7-10. Sound-activated flashgun trigger. (a) Block diagram. (b) Circuit diagram of a solid-state switch, flash tube and power supply.



Circuit diagram of a flash tube unit you can make. Be careful in constructing high-voltage pulse circuits such as this. Ask a teacher to check the unit before you turn it on!

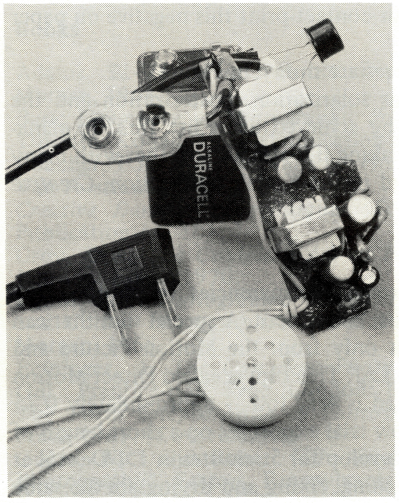


Figure 7-11. A complete flash trigger mounted on a board.

Component	Radio Shack serial #
Crystal microphone	270-095
IC 741	276-1741 or 276-007
SCR_1	276-1020
T_1	272-1146
Xenon flash tube	272-1145
40 μF electrolytic	272-104
D_1, D_2 400 P.I.V. silicon diodes	276-1103
0.1 μF electrolytic	272-1053
200 μF photoflash capacitor — computer grade or better	

You can use this technique for many investigations as long as the event produces a sound. By adjusting the amplification provided by your equipment, you can make the method sensitive enough to record what happens when drops of milk fall into a dish, for instance.

Topic 8: Using 'lith' film

'Lith' film is obtained from suppliers such as Ilford and Kodak. It is made in such a way that it has extremely high contrast. When processed in the correct developer, the silver bromide crystals are either unaffected or are *completely* changed to silver. Thus, after fixing, the negative shows only two types of area, clear film and a completely black image. Prints made from this negative show no grey tones. Such prints are extensively used in the graphic arts industry. The title page of *Chemistry of the Car* in this series is one example.

The film is obtainable as 35-mm roll film. You can find the best exposure only by experiment. For a rough guide, assume that the film speed is about 5 ASA.

When using the film in sheets, you can take advantage of its insensitivity to red light and use it in the darkroom as you handled paper in Experiment 2-4. Place a negative in your enlarger, project an image onto the lith film and make a high-contrast positive by placing the film in developer solution for 3 minutes. After fixing, washing, and drying this positive, you can place it in contact with a piece of paper in the darkroom, and make a high-contrast negative print.

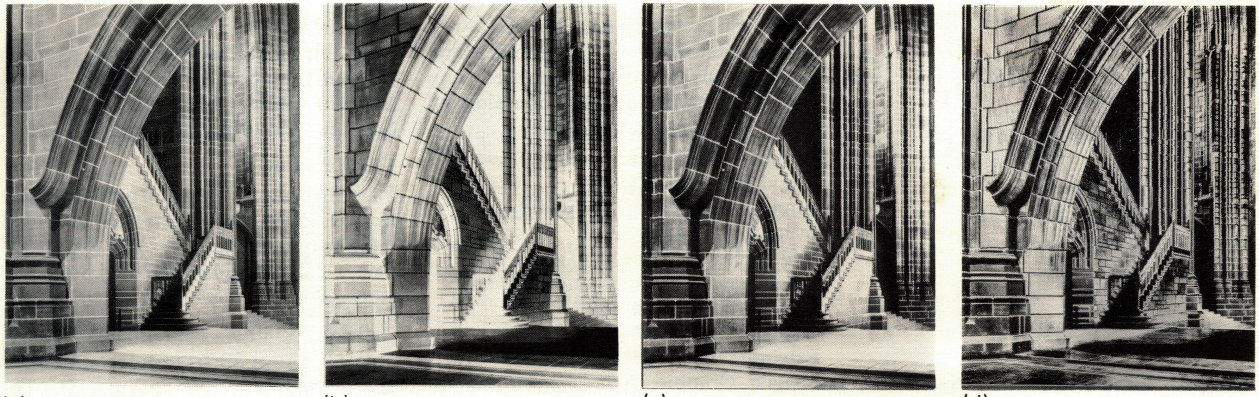
If you want to make a high-contrast positive print, you must contact-print your positive lith film image onto another piece of lith film, which will then develop into a negative. Then you can contact-print this negative on paper to give a positive.

Some examples of these procedures are shown in Figure 7-12.

Many interesting effects, such as solarization, posterization and the creation of tone-lines and bas-reliefs can be achieved using lith film. Explanations of these terms and instructions for making the effects, together with many other ideas for further work, can be found in the Kodak publication, *Creative Darkroom Techniques*.

Topic 9: Making monochrome transparencies easily

If you have a large number of monochrome transparencies to produce, the method described on page 20 is not the most convenient. A special film that can be used for this purpose is available, but only from the Motion Picture and Audio-Visual Marketing Division of Kodak Ltd. This film is called Direct Motion Picture and is bright red in colour. Its speed is very low – approximately 0.75 ASA – so that you will have to make a few trial exposures on a short length of film. However, processing is very simple: develop for 5 minutes in 1:1 Dektol at 20°C, with agitation every 30 seconds. Washing, fixing and drying are the same as for any other film you have used. The slides obtained are of superb quality, and copies of transparencies and prints, made with this film, often appear superior to the original.



(a) (b) (c) (d)

Figure 7-12. Photographs produced by using 'lith' film. (a) Original scene. (b) High-contrast negative. (c) High-contrast positive. (d) Negative tone line, made from a sandwich of the negative and positive.

There are still several processes and films that you have not tried. Kits of paper, chemicals, filters and processing drums for producing photographs such as the one on the right-hand colour page in the centre of this book are available from Kodak, Agfa and Unichrome. The Cibachrome process can be used by the amateur to produce colour prints directly from transparencies. The dyes are diazo compounds, as mentioned on page 34.

Reference materials

Books

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Mees, C.E.K. *Theory of the Photographic Process*. Don Mills, Ont.: Collier-Macmillan, 1966.

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Paul, D., et al. *The Nature of Light and Sound*. Toronto: Holt, Rinehart & Winston, 1974.

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Watson, J.N. *Pictures in Silver*. London: Longman, 1968.

The commercial photographic houses (Kodak, Ilford) produce a large range of booklets especially for schools.

Films

Many films are available from the National Film Board of Canada to illustrate the use of different photographic techniques. These include:

'Carrousel'. 16 mm, colour, 10 minutes; and

'This solitude through which I go is I'. 16 mm. black and white, 30 minutes.

The special effects films created by Norman McLaren of the National Film Board are world famous.

Special materials for experiments

This is a list of special materials not normally stocked in a school laboratory but which would be needed for a class of thirty students to complete all the experiments in this book.

Aminoethanoic (aminoacetic) acid (glycine) (250 g)
Ammonium polysulfide (100 cm^3)
Butanedione dioxime (dimethylgloxime) (10 g)
Concentrated sulfuric acid (100 cm^3)
1,4-dihydroxybenzene (hydroquinone) (500 g)
Ethanoic (acetic) acid (5 dm^3)
Kodak Graphic Arts Film, Type 3 Ortho, #6556, 10 × 12.5 cm (50 sheets)
4-methylaminophenol (elon, metol) (100 g)
Nickel nitrate (100 g)
Phenidone (50 g)
Potassium bromide (50 g)
Potassium chloride (25 g)
Potassium dichromate(VI) (100 g)
Potassium hexacyanoferrate(III) (potassium ferricyanide) (500 g)
Potassium iodide (25 g)
Potassium manganate(VII) (potassium permanganate) (100 g)
Silver nitrate (10 g)
Sodium disulfate(IV) (sodium metabisulfite) (500 g)
Sodium metaborate (100 g)
Sodium sulfite (1 kg)
Sodium thiosulfate (5 kg)

Chapters 2 and 7

Page 8 (Chapter 2) and Topic 8 (Chapter 7). NegaFile sheets are available from suppliers such as Vue-All Proof File, Ocala, Florida 32670, U.S.A.

Chapter 7

Topic 4. A movie camera lens is available for about $3 from Edmond Scientific Products, 3500 Bathurst St., Toronto, Ont. M6A 2C6

Topic 5. A microscope adapter is available for about $10 from Edmund Scientific Products.

Topic 7. Electronic components are obtainable from branches of Radio Shack.

A 150 cm^3 container of liquid photographic emulsion for printing a photograph on an egg or other materials is obtainable from Diversey-Creation Co., 252 South Hillside, Wichita, Kansas 67211, U.S.A., (page 16).

Word meanings

Acid — A substance that dissolves in water and increases the hydronium ion concentration.

Additive mixing — The process by which beams of red, blue, and green light combine to give white light.

Agitation — Movement of a tank or dish to ensure that the emulsion is always in contact with fresh solution. For film, this is usually once per minute; for paper, once each 10 seconds.

Alkali — A substance that dissolves in water and reduces the hydronium ion concentration.

Aperture — The opening in a lens through which light passes. This is usually adjusted in a series of fixed steps. See f-number.

B ('Bulb') — The shutter setting at which the light travels through to the emulsion for as long as the shutter button is held down.

Buffer	A solution which contains a weak acid or weak alkali, and one of its salts. Such a solution resists changes in pH.
Cassette	The light-tight containers in which are stored films that do not have a backing paper.
Compensation	Development of a film in such a way that the shadows are made more intense in the negative and the highlights are made less dark.
Contrast	The difference in reproduction between darker and lighter parts of a picture. The maximum contrast range produced on most photographic prints is 50:1.
Cropping	Altering the ratio of the dimensions of a picture, or the ratio of the main subject to the total area.
Density	The relative darkness of a print or opacity of a transparency.
Depth of field	The range of distance from the lens over which an object is still reproduced on the film as a sharp image.
Developer	A solution of a substance that changes silver ions in the latent image to silver atoms.
Emulsion	The layer of light-sensitive material (gelatin and silver halides) on photographic paper and film.
f-number	The ratio of the aperture of a lens to its focal length.
Film speed	The relative sensitivity of a film to light.
Fixer	A solution used to remove unchanged silver halide remaining in the emulsion after development.
Fluorescence	Absorption of energy of wavelength outside the visible spectrum by a substance which *immediately* emits radiation at a wavelength within the visible spectrum.
Focal length	The distance from the optical centre of a lens to the point at which an object at infinity forms an image.
Grain	The texture of a developed emulsion which is visible on magnification. It is caused by the clumping together of silver atoms.
Halides	Salts of fluorine, chlorine, bromine and iodine.
Infinity	The symbol on a focusing scale representing great distance: ∞.
Intensification	Increasing the density of a photographic image.
Latent image	The effect of light on photographic emulsion before development.
Oxidation	Removal of electrons from an atom, group of atoms or an ion.
pH	A measure of the hydronium ion concentration of a solution. Pure water has $pH = 7$. Acids have $pH < 7$ and alkalis have $pH > 7$.
Phosphorescence	Absorption of energy of wavelength outside the visible spectrum which *slowly* emits radiation at a wavelength within the visible spectrum. Thus phosphorescence continues after the activating radiation has been turned off.
Preservative	A substance that opposes oxidation of a developer.
Reduction	(a) Transfer of electrons to an atom, group of atoms or an ion. (b) Decrease in the density of a photographic image.
Restrainer	A substance, often potassium bromide, in a developer to keep the unexposed portion of a film from becoming fogged during the development.
Safelight	A light source of longer wavelength than that light which affects photographic emulsion.
Washing	Rinsing an emulsion with enough cold water to remove all thiosulfate ions.

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